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A TREATISE ON

THE COMMON SOLE

(SOLEA VULGARIS),

CONSIDERED BOTH AS AN ORGANISM AND AS A COMMODITY.

PREPARED FOR THE

MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM

BY

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PUBLISHED BY THE ASSOCIATION.

1890.

LONDON:

HARRISON AND SONS, PRINTERS IN ORDINARY TO HER MAJESTY,

ST. MARTIN'S LANE.

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PREFACE.

The distinction between theory and practice is one that is generally recognised in all departments of human affairs. By theory in this context is meant pure knowledge—the knowledge of things as they are apart from any use which may be made of the knowledge. This kind of knowledge—the result of the most careful investigation, continually corrected by improved experiments and more widely extended observation, and subjected to the most rigid criticism by successive generations of enquirers—is pure science. Practice, on the other hand, or practical knowledge, is the knowledge of the methods by which the material and the forces of nature can be made to satisfy human needs and desires. Practice necessarily depends on some knowledge of the properties and relations of natural objects and forces, though in many cases it may simply consist in knowing that a certain desired result will generally be produced by particular operations. This is the kind of knowledge possessed by men trained and experienced in particular "trades" or crafts.

The distinction has existed since the very commencement of human civilisation. The earliest representatives of humanity, like the most primitive savages now existing, had some knowledge of their surroundings which was not directly useful to them, while they understood very little the arts which they practised. To some extent the development of pure science and that of practical science have proceeded independently, but to a large extent they have influenced one another. Practical science has often received a great impetus from the discoveries of abstract inquiry, and pure science has often made enormous strides by the study of the results exhibited by industrial processes. On the whole the tendency of the development of the two is towards a perfect harmony in which the knowledge of the universal interaction of natural forces would completely

explain all that takes place in industrial processes, and on the other hand industrial processes would be perfected by the application of a complete knowledge of the mechanism of nature.

Thus, although there is a great distinction between science and practice, each is to a large extent dependent on the aid of the other. Their influence upon each other could be illustrated by the history of any branch of science: it is illustrated by the history of biological arts and sciences. The discovery that the great depths of the ocean were inhabited by living animals was directly due to the laying of the telegraph cable from Europe to America. The medical sciences, anatomy and physiology, sprang not solely from the desire for knowledge, but from the practice of the healing art, and the desire to improve that art. Botany took its rise from the knowledge of simples, the use of plants as remedies for diseases and disorders of the human body. Zoology and comparative anatomy and physiology have been largely aided in their development by the medical sciences. Marine zoology has ever been to a great degree dependent on the assistance of fishermen and fishing engines. Science has received definite additions from investigations carried out with the object of cultivating oysters. The explanation of evolution is sought in the study of the variations of domesticated animals and plants. Are there, on the other hand, any cases in which human arts and industries have directly benefited by the biological sciences? To answer this question by even briefly enumerating the recent discoveries concerning animal and vegetable parasites which have revolutionised the practice of agriculture would require a volume. But it must be confessed that the fishing industry has hitherto, in this country at least, not been greatly benefited by the scientific knowledge of fishes hitherto available. Yet zoological science and the methods of that science have not been entirely without effect upon the supply of aquatic animals for the wants of man. Oyster-culture based upon scientific knowledge has been very successful in Holland and France. Knowledge of the conditions of life of the salmon has been applied to maintain and increase the abundance of that fish in this country, and of allied fishes in America. The shad has been propagated with great success on the Atlantic coast of the United States. It remains true that there exists a great deal of scientific knowledge of marine fishes which has hitherto not at all affected the sea-fishing industry. But it is also true that no great endeavours have yet been made to bring science and practice in this direction into relation with one another, and also that our knowledge of the life of marine fishes is in many respects still extremely

limited. The structure of these fishes and their place in the general classification of the animal kingdom has been to some extent ascertained, but of their conditions of life, their food, rate of growth, the causes which favour or limit their abundance, we still know very little. It was only in 1864, when Professor Sars identified the floating eggs of the cod, that it was first discovered that the eggs of any marine fish passed through their development while suspended in the surface waters of the sea. The knowledge of structure and classification is not entirely useless from the practical point of view, for it is absolutely necessary as a basis from which to investigate the different conditions of life of the different species. The species must be considered separately, for their mutual relations are so complicated that it is impossible to deal with them together.

The object of the present work is to place side by side the results of a scientific study of the common sole and an account of the present condition of the sole fishery, and then to consider what are the possible practical applications of the former to the purpose of maintaining or increasing the supply of soles available for the market.

The work was undertaken under instructions from the Council of the Marine Biological Association, and the investigations described were carried out at the Association's Laboratory at Plymouth. Nearly the whole of my time and energy since November, 1888, have been devoted to the subject. The instructions of the Council were quite general, but from Professor Lankester I have received much guidance as to the scope of the investigations and the plan of the book. The responsibility, however, for all the views and statements rests entirely upon myself. When studying the taxonomical part of the subject in November, 1889, I visited the British Museum of Natural History, and examined all the type specimens of European species of sole. I have to thank Dr. Günther for the courtesy and assistance I then received from him. At that time I gathered from conversations with him that he still believed in an English species, *Solea aurantiaca*, distinct from the *Solea lascaris* of either Risso or Bonaparte. I was therefore surprised to see that in a communication to the Zoological Society in January last he abandoned this opinion, and adopted the conclusion of most recent writers on the subject—that the English and the Mediterranean form belong to the same species. My discussion of the question in the present work was written in November, 1889, immediately after my visit to the national collection.

I have much pleasure in thanking Mr. Dunn, of Mevagissey, and my friend Rupert

Vallentin, Esq., of Falmouth, for the most important assistance they rendered me in procuring specimens of the sole in the younger stages of growth. I am still more deeply indebted to Miss Annie Willis for the skill and care which she devoted to the water-colour drawings reproduced in Plates I to IX. The beauty, minuteness of detail, and artistic finish of her work are evident enough in the lithographic copies, and I need only add that the drawings were executed from the actual objects under my direct supervision, and that I can answer for their perfect faithfulness.

J. T. C.

Plymouth,
March 13, 1890.

PART I.

TAXONOMICAL.

CHAPTER I.

CLASSIFICATION OF THE FLAT-FISHES.

It is a matter of general knowledge and experience that the various kinds of flat-fishes resemble one another and differ from all other fishes in these conspicuous features: that their form is very flat, that one side is coloured and the other of a pure opaque white, and that there are two eyes on the coloured side and none on the white side. It is further generally known, from the observation of such fishes in the living state in aquaria, that when alive they are usually resting on the white side at the bottom of the water, sometimes gliding gently over the ground, sometimes burying themselves in the sand, which is the material on which they are accustomed to live, and only occasionally rising up from the bottom and swimming in a horizontal position through the water. The common sole is also as a rule recognised by everybody as a particular kind of flat-fish, being readily distinguished by its gently curved outline, especially by the regular, almost semicircular, shape of the snout, and by the dull brown colour of its upper side after death.

But this is only true of the sole as it is usually seen by the majority of people, that is in its adult condition. Ordinary habits of observation are not sufficient to distinguish the sole in its very young condition from other kinds of flat-fishes: only naturalists are able to separate the kinds from one another among individuals from one to three inches in length. Even fishermen, who might be supposed to have unusual opportunities of comparing different kinds of fishes, but who, as a matter of fact, have usually no leisure and no superfluous energy to devote to accurate and minute observation, constantly mistake various kinds of flat-fishes in their young stages for young soles. The reason of this is not that the young fishes between one and three inches long differ in their characters from full-grown specimens, but simply that the characteristic features are on a much smaller scale, and therefore are not seen without attentive observation.

Untrained powers of observation are also unable to compare the degree of difference between one kind of flat-fish and another. The plaice and flounder are named independently; but a fish which resembles the plaice and flounder far more closely than it does the sole is sold under the name of merry-sole in Devonshire and lemon-sole in London. This may be partly due to an inclination to enhance its value in the

eyes of the consumer. Again, more than one kind of sole is sometimes sold under that name.

It is evident, then, that before we commence the study of the common sole we must make ourselves accurately acquainted with its special features, so that we may not mistake other kinds for it, and may identify it with certainty at all stages of its existence. In order to discover these special features we must compare all the kinds of flat-fishes with other fishes and with one another and thus ascertain—1st, what features are common to all of them; 2nd, what features are common to certain divisions of them and especially to the division which includes the sole; 3rd, what are the differences between the several kinds or species included in this particular division.

In order to study the characters of the flat-fishes we must of course give names to their various organs; but all the bony fishes are made up of the same organs in different shapes and sizes and in various proportions to one another. Thus we have only to examine the sole and compare it with a fish of the more usual structure in order to recognise the various organs which have long borne appropriate names.

In any fish of the ordinary type, for example, a salmon, herring, cod, perch, mackerel, &c., the two sides resemble one another in form, structure, and colour, and correspond to one another in the position and direction of their component organs. In other words, all the organs, with the exception of some of the internal, are in pairs, the two members of each pair being situated on opposite sides of the middle plane of the body, at the same level, and at equal distances from it. This plan of structure occurs in the majority of fishes and nearly all the other vertebrates, and also in the greater number of the lower animals, for instance in crustacea and insects. To obtain a distinct idea of it we may reflect that the body of any animal in which it occurs, say a normal fish, a dog, or a man, has length, thickness, and breadth. The length is measured from the head to the posterior end of the body, the thickness from the back to the ventral surface, the breadth from side to side. Now the organs at opposite ends of the line which measures length are utterly different in form and structure, and those at the back are equally different from those opposite to them at the ventral surface. But, wherever we measure the breadth, the parts at one end of the line along which we measure will be exactly similar in form and structure to those at the other, but exactly reversed in horizontal direction. This structural feature is called bilateral symmetry.

The greater number of fishes are bilaterally symmetrical, and the line along the surface which separates the two similar halves passes between the eyes at an equal distance from each. If we look for the line which divides two similar halves in the sole we shall not be able to find it. It is obvious that a line drawn between the eyes does not divide the head into two equal and similar parts; but if we look for the paired organs of the ordinary fish in the sole we shall find in most cases that one of each pair is on the coloured or upper side of the sole, and the other on the white or lower side, but that in many cases the two members of each pair are not so exactly

similar as they are in the ordinary fish. Thus in the sole there is a gill-cover or operculum on the upper side and another on the lower, and beneath each is a similar gill-apparatus; half the mouth is on the upper side and half on the lower; there are two nostrils on the upper side and two on the lower; a pectoral fin and a pelvic fin on the upper side and two corresponding fins on the lower; scales on the upper side and similar scales with a corresponding arrangement on the lower; and finally a line of peculiar scales, a lateral line, along the middle of the upper side and a similar line on the lower. It follows, therefore, that the long continuous fins along the two edges of the sole correspond to the median fins of the ordinary fish, and as we find the anus and the junction of the gill arches on one edge of the sole, this edge corresponds to the ventral median line of the ordinary fish, so that the elongated fringing fins of the sole are the dorsal and ventral median fins respectively; the ventral median fin is generally called the anal fin. We thus find that the upper side of the sole is the right side and the lower the left, and the edge on which the anus opens is the ventral edge, the other the dorsal. But the two eyes, though in other respects similar to the two eyes of an ordinary fish, are both on the right side, one nearer to the dorsal edge, the other nearer to the ventral. We may distinguish these eyes as the dorsal and ventral respectively, and even without further knowledge we might consider it probable that the dorsal eye corresponds to the left eye of an ordinary fish and the ventral to the right, and the idea would naturally occur to us that the left eye in the sole had been somehow drawn out of its original position on the left side and carried round to the right side.

The fins of the sole are all supported by flexible or soft rays; none of the rays are rigid pointed spines; but this is a character which occurs in certain symmetrical fishes, for example, the cod and whiting. The possession of a single elongated median dorsal fin and a single similar ventral fin is also not peculiar to the sole: some members of the cod family have but a single dorsal and ventral fin. But no symmetrical fish has a dorsal fin extending so far forwards as the sole: in the latter this fin is continued to a point on the edge of the body anterior to the eyes, and in every flat-fish, except one species, it extends at least as far as a point above the dorsal eye, while in all symmetrical fishes the limit is somewhat behind the eyes.

The lower or left side of the sole differs from the right side not only in being white instead of coloured, but also in being flatter, and the fin-rays of the median fins are also more prominent on this side.

The examination of other flat fishes will show that they resemble the sole and differ from symmetrical fishes in the features just mentioned, if we except the fact that in some kinds it is the left side and not the right which is coloured and which bears the eyes. Thus the turbot and brill have the eyes on the left side, while the plaice flounder, dab, and halibut, like the sole, have them on the right side.

All the various kinds of flat fishes thus resemble one another and differ from symmetrical fishes in the particulars now described, which may be thus summarised:—

Body much compressed bilaterally and extended dorso-ventrally: one side, on which the fish rests during life, opaque white, flatter than the other, which is more convex and exhibits colour and markings: both eyes on the coloured side of the head. Pectoral and pelivc fins small, the former sometimes absent; a single elongated dorsal fin which extends forwards as far as or beyond the level of the dorsal eye, except in one instance where it ends a little behind the eye; a single elongated anal fin extending from the base of the tail to the anus, which is a short distance behind the opercular apertures.

The fishes thus characterised form a single family—the *Pleuronectidæ* (= side-swimmers, from Greek πλευρά, the side; νήχω, I swim). The large number of kinds or species which can be distinguished among them are divided into a number of groups according to the degree of difference between them, any two species of the same group being much more closely similar to one another than to the members of any other group. These groups are the genera. Thus the difference between a plaice and a sole is much greater than the difference between a plaice and a flounder. The plaice and the flounder resemble each other in the shape of the body, in the large prominent eyes, and the small terminal mouth and pointed snout. Again, if we compare a turbot and a brill we find that they resemble one another very closely: they both have a deep straight mouth cleft, the anterior end of which is at the extreme apex of the snout, and both have a more or less rhomboidal shape.

The various kinds of sole are all distinguished from other flat fishes by the gradual and regular curve formed by the outline of the body, which, excepting the tail, is almost a perfect oval, the semicircular form of the snout being specially characteristic. The dorsal fin commences on the snout, and is not continuous with the caudal fin; the cleft of the mouth on each side is curved downwards. The mouth is asymmetrical, the jaws being stronger on the lower side, and only on this side containing teeth, which are small and slender. The eyes are on the right side and small, the dorsal being in advance of the ventral. The scales are small and fringed with small projecting spines, that is, are of the kind called ctenoid. The lateral line is straight from the head to the tail, and runs along the middle of each side, but it also sends a curved branch forwards on the head which runs parallel to the base of the dorsal fin towards the snout.

All the *Pleuronectidæ* exhibiting the above features are called *Solea*, with a distinguishing adjective to indicate the particular kind or species referred to. In other words, the species which resemble one another in these particulars and differ only in more minute details are classed together in a genus which bears the Latin name *Solea* in the universal language of Zoology.

There are other kinds of sole besides the common sole, that is to say, there are other kinds of flat-fishes which resemble the sole in all the features in which the sole differs from the turbot or the flounder, but differ from it in more minute details. One kind is sometimes sold together with the common sole without being distinguished, and sometimes is distinguished as the sand sole. It differs from the common sole chiefly

in two characters: (1) it is somewhat lighter in colour after death, and instead of large black blotches on the coloured side it has small black specks scattered almost uniformly over the surface; (2) the anterior nostril of the lower side is very large and conspicuous, it is dilated and has folds radiating from its wall into its cavity. At Plymouth and other places on the south coast of Devon and Cornwall another flat-fish is commonly sold which is called the thick-back. This is evidently a kind of sole, but is distinguished by its smaller size, and by its colour and marking, which consists of black transverse stripes on a red ground.

Several kinds of flat-fishes are obtained from British seas, which are too small and too scarce to be of any value as food, but which of course have been studied by zoologists equally with the edible species.

After studying all the species of flat-fishes brought together in the British Museum from all parts of the world, Dr. Günther has classified them in thirty-four genera, including Solea. But of these only seven include species which occur on the British coasts. Zoologists often differ as to the limitations of genera, because it is in many cases difficult to decide whether several species differ from one another to an equal degree and ought therefore to be classed in a single genus, or whether they differ in different degrees and ought to be separated into two or more genera. Recent authorities also recognise seven genera among British forms—namely, *Hippoglossus*, *Hippoglossoides*, *Rhombus*, *Zeugopterus*, *Arnoglossus*, *Pleuronectes*, and *Solea*. The external differences which distinguish the genera and species of British forms may be presented analytically thus:—

A. Eyes on the left side; mouth terminal; teeth on both sides; ventral eye anterior to the dorsal.

1. *Rhombus*. Shape rhomboidal, middle of the body being very broad; mouth large; lateral line with a semicircular curve anteriorly.

   Rhombus maximus, the Turbot. No ordinary scales, but pointed tubercles uniformly scattered over skin.

   Rhombus lævis, the Brill. Small scales; no tubercles.

2. *Zeugopterus*. Shape almost rectangular, anterior end obtuse; lateral line with a semicircular curve anteriorly; scales ctenoid.

   Zeugopterus unimaculatus, first dorsal ray elongated and undivided, median fins not prolonged under the base of the tail; a conspicuous large dark spot towards the posterior end of the lateral line.

   Zeugopterus punctatus, first dorsal ray not elongated, median fins prolonged under the base of the tail.

3. *Arnoglossus*. Shape oval, rather narrow, with sharp snout; eyes large, almost level, ventral slightly more advanced. Cleft of mouth deep. Teeth small, one or two rows in both jaws; present or absent from the vomer; none on the palatines. Gill-membranes somewhat broadly united

at the throat. Dorsal fin commencing on the snout in front of the eyes, and not continuous with caudal. Nearly all the rays of the dorsal and anal simple and undivided. Scales somewhat large, easily detached, ctenoid. Lateral line with a rectangular bight above the pectoral.

Arnoglossus megastoma (Megrim at Plymouth). Teeth on the vomer. Anterior dorsal rays united by membrane for half of their length. The base of the dorsal fin not passing on to the lower side of the head anteriorly. Anterior nostril of the lower side protected by a broad flap of flexible membrane. Eyes very large. Scales not so deciduous as in the following species. Snout pointed.

Arnoglossus laterna (Scald-fish or Scald-back at Plymouth). No teeth on the vomer. Anterior dorsal rays free and separate; the membrane of the rest of the fin very slight, the rays easily becoming separate. The anterior rays of the dorsal fin arise from the lower surface of the head. Eyes not very large. Snout somewhat blunt. The base of the left pelvic fin extends from the throat to the anus, and behind it are one or two prominent spines. The four anterior rays of the dorsal fin are very thick and much elongated in the male, not in the female. *Arnoglossus lophotes*, Günther, is the male.

B. Eyes on the right side.

I. Mouth terminal and large, teeth on both sides.

1. *Hippoglossus.* Shape lanceolate; dorsal fin commencing above the dorsal eye; scales cycloid. Lateral line with a slight curve anteriorly.

Hippoglossus vulgaris, the Halibut.

2. *Hippoglossoides.* Anterior end not much narrowed; dorsal and ventral edges rather straight; scales ctenoid. Lateral line straight.

Hippoglossoides limandoides, the Long Rough Dab.

II. Mouth terminal and extremely small; teeth most developed on the lower side.

1. *Pleuronectes.* Dorsal fin commencing above the dorsal eye; eyes large and prominent; scales small or rudimentary.

Pleuronectes platessa, the Plaice. Bony tubercles on the interorbital ridge. Bright red spots; scales uniform. Lateral line nearly straight.

Pleuronectes microcephalus, the Merry-sole or Lemon-sole. Skin slimy. Lateral line with a very small anterior curve. Colours mottled with a good deal of yellow; scales cycloid. Shape somewhat rectangular.

Pleuronectes cynoglossus, the Pole-flounder or Witch. Shape elongated; dorsal and ventral edges very gradually curved. Lateral line straight.

Pleuronectes flesus, the Common Flounder. Ossicles at base of dorsal and anal fins. Scales rough along lateral line, elsewhere rudimentary.

Pleuronectes limanda. Shape rhomboidal; snout pointed. Lateral line with a small semicircular curve anteriorly.

III. Mouth rather small, and not terminal, but curved down to the ventral edge; teeth present only on the lower side.

1. *Solea.* The shape oval, outline of the snout regularly semicircular. Scales ctenoid. Lateral line straight, but with an anterior dorsal curve on the head. Tactile filaments on the lower side of the snout. Paired fins may be rudimentary or absent. The dorsal eye anterior to the lower.

Solea vulgaris, the Common Sole. Pectorals on both sides of considerable size; nostrils on the two sides similar; filaments of the under side of the snout closely crowded together not forming any pattern. Markings of the upper side consisting of longitudinal series of black blotches on a yellowish-brown ground.

Solea lascaris, the French Sole or Sand Sole. Differs from the preceding in two characters—viz., the anterior nostril on the lower side is dilated and fringed internally; each of the black blotches of the preceding species is represented by a number of small black specks.

Solea variegata, the Thick-back. Nostrils on both sides similar; pectoral and pelvic fins rudimentary; filaments of the lower side of the snout connected at their bases by membranes which surround square depressions. Mouth more terminal and less curved than in the other species. Markings consist of five transverse dark bands.

Solea lutea. Resembles the preceding in other respects, but has the mouth much curved, the dorsal fin commencing on the extreme anterior end of the snout. The markings consist of dark blotches arranged as in *S. vulgaris*, but there is in addition a thin black line along every fifth or sixth ray in the dorsal and anal fins.

Solea Greenii, a new species just defined by Dr. Günther, has the scales, fin-rays, and filaments of the left side of the head as in *vulgaris*, but rudimentary pectorals.

Plates I to VII, which exhibit with great accuracy the natural appearance of the fish, will illustrate the distinguishing external features of the four commoner British species of sole. But although the above-mentioned characters are those which principally distinguish the species from one another, they do not exactly resemble one another in every other respect. We may proceed to study their characters in greater

detail, in order to obtain a complete knowledge of their specific peculiarities. In describing the characters of a fish, it is usual to commence by counting the fin-rays in each fin, the number of scales in the lateral line, wherever this is possible, the number of vertebræ, and the number of rays which support the membrane covering the gills beneath the operculum; these are called the branchiostegal rays. These numbers are all put down in succession with initial letters to indicate the organs they refer to, so as to form a numerical formula. Thus :—

B. = Branchiostegal.	Pt. = Pectoral fin.
D. = Dorsal fin.	Pv. = Pelvic fin.
A. = Anal fin.	C. = Caudal fin.
L.l. = Lateral line.	Vert. = Vertebræ.

The proportions of the fish are expressed numerically by stating the number of times a given length is contained in the total length: the reason of this is that the measurements are made with a pair of compasses, which are first adjusted to the length of a certain organ, and then used to mark off successive lengths equal to this along the body-length.

CHAPTER II.

HISTORY OF THE GENUS *SOLEA*.

The flat-fishes have been always placed together in one group in all attempts to classify fishes from the time of the ancient Greeks and Romans up to the present. Thus Aristotle called them ψηττώδεις. But in ancient times other fishes of a flat shape, but symmetrical, like the dorey and the skate, have often been united with them. Thus Rondelet includes among the "poissons plats" the dorey and two other symmetrical fishes and all the skates and rays. In the ancient and pre-Linnæan times ideas of classification were somewhat vague; the idea of genus and species existed, though it was not accurately defined, but degrees of classification regularly subordinated to one another could not be established by men who had little real knowledge of the structure and physiology of animals. Rondelet includes all marine animals among his "Poissons," yet his arrangement of the true Pleuronectidæ in genera and species is more similar to that which is now accepted than the classification adopted by Artedi and Linnæus. Rondelet describes the genus *Rhombus* with two species, one with spines and the other without, the turbot and the brill; the genus *Rhomboides*; *Citharus* with two species; *Passer* with four species, *Passer*, the plaice, *Passer quadratulus*, *Passer limanda*, and *Passer flesus* (the flounder); the genus *Solea*, with six species, *Solea*, the common sole, *Solea oculata* (*la Pégouse*), *la Pole*, *Arnoglossus*, *Solea lingula*, and *Hippoglossus*.

Artedi arranged all the flat fishes into one genus—*Pleuronectes*, a name which he introduced into zoology for the first time, and Linnæus followed his example. The 12th edition of the "Systema Naturæ" was published in 1766. The successors of Linnæus for some time continued to follow him and Artedi, merely dividing the genus in an arbitrary way into subgenera. Lacépède, in his "Histoire Nat. des Poissons," published in 1798, defines four subgenera of *Pleuronectes*, but without giving them distinguishing names: the first of them comprises only the halibut and the flounder, united because their eyes are on the right side and they have a curve in the lateral line. Similarly, Risso, in his "Ichthyologie de Nice," 1810, arranges the species under two subgenera, according to the side on which the eyes are situated.

Quensel in 1806 divided the genus into two, with the following definitions:—

Pleuronectes, having complete jaws not covered with scales; the maxillary dilated

and free at its extremity; the mandible with cutaneous folds between its limbs at the chin. Gill-opening extending above the opercular angle or at least above the pectoral. The lower eye more anterior than the upper one, and the nostrils distant from the jaws, that of the blind side being near the dorsal edge.

Solea, in which the jaws are covered with scales, the superior one not fully developed, and the scaly mandible not showing the usual folds at the chin. Gill-openings wholly below the pectorals. The inferior eye farther back than the superior one. Nostrils on both sides near the jaws. All the fin-rays divided, no spine in the anal. (Richardson's Yarrell, Vol. I., p. 608.)

In the "Règne Animal," first edition, 1817, Cuvier makes the Linnæan genus into a family, which he calls simply "poissons plats," and divides it into genera and species as follows:—

Platessa, including the plaice, *Platessa platessa;* the flounder, *Platessa flesus;* the dab, *Platessa limanda.*

Hippoglossus, including the *Pl. hippoglossus* of Linnæus, and several species of the Mediterranean described by other authors.

Rhombus, including *Rhombus maximus*, the turbot and the brill, the *Pl. nudus* of Risso (apparently an *Arnoglossus*), and other species in which the upper eye is at a great distance above and behind the lower.

Solea, including the common sole, *Pl. solea*, Lin., the *Pole* of Belon, the *Solea oculata* of Rondelet, the *Pégouse* of Risso, and the *lascaris* and *theophilus* of the same author. Also certain foreign species in which the vertical fins are continuous, *Pl. zebra*, Bloch, *Pl. plagusia*, Lin. (These species now form the genus *Plagusia.*)

The *Monochires*, in which the right pectoral is very small, and the left minute or altogether wanting, *e.g.*, *Linguatula*, Rondelet, and the *Achires*, which have no pectorals at all, are mentioned apparently as subgenera. Those *Achires* in which the vertical fins are continuous with the caudal are distinguished as *Plagusia.*

The definition of *Solea* given by Cuvier is as follows:—

"Their peculiar character is that the mouth is twisted and as it were monstrous on the side opposite to the eyes, and furnished on that side only with slender teeth closely crowded together like the pile of velvet, while the side where the eyes are has no teeth. Their form is oblong, their snout round and always projecting beyond the mouth; the dorsal fin commencing over the mouth, and extending like the anal up to the caudal. Their lateral line is straight; the side of the head opposite to the eyes is generally furnished with a sort of villosity. Their intestine is long, with several convolutions, and without cæca."

It is evident that this definition of the genus admits of but little improvement. Cuvier obviously meant the *Monochires*, *Achires*, and *Plagusia* to be mere subgenera

indicating the grouping of the various species. But subsequent authors frequently raised these divisions to the rank of distinct genera. Bonaparte, 1841, separated the last subdivision of Cuvier only as a distinct genus, namely, *Plagusia*.

Dr. Günther, in his important work, "The British Museum Catalogue of Fishes," gives a comprehensive classification of the Pleuronectidæ, which includes all the forms up to that time described in the literature or represented in the great national collection. He distinguishes in all thirty-four genera, many of which are entirely new, while the limits and definitions of the rest are revised. His definition of *Solea* is as follows:—

Eyes on the right side, the upper being more or less in advance of the lower. Cleft of the mouth narrow, twisted round to the left side. Teeth on the blind side only, where they are villiform, forming bands; no vomerine or palatine teeth. The dorsal fin commences on the snout, and is not confluent with the caudal. Scales very small; ctenoid. Lateral line straight.

Thus the chief difference between this definition and Cuvier's is that it excludes all the forms in which the longitudinal fins are continuous with the caudal. All the British forms of sole described in the present work are included by Günther in the genus *Solea*. But almost every author defines the genera of Pleuronectidæ, even at the present day, in some degree after his own fashion. There is a general agreement, together with differences of opinion on certain points. In the Pleuronectidæ, as in nearly all families of animals, there are certain well-marked *species* which are recognised by all naturalists. There are others, especially those founded upon a small number of specimens, which are more difficult to separate, and concerning which differences of opinion exist. But the question of the arrangement of the species into genera gives rise to much greater differences of opinion. The arrangement of course depends on which of the characters possessed by several species in common, are taken as characterising a genus. If one character is taken, a certain number of species are united by it; if another is taken the same species are scattered among other genera. Thus the fish called in this work *Arnoglossus megastoma* is variously placed. By Günther it is placed in the genus *Rhombus*, because it possesses teeth on the vomer. By Moreau, whose arrangement seems to me more original than natural, it is placed in the genus *Pleuronectes*. The characters in which the species agrees with *Arnoglossus laterna* seem to me to be more numerous and important than the presence or absence of vomerine teeth, and I have therefore followed those authors who include it in the genus *Arnoglossus*.

In describing the British species I shall give not merely the range of variation of each numerical character, but the actual numbers observed in several individuals. It must be pointed out that the number of scales in the lateral line is always obtained not by counting the scales in the line itself, but the series of oblique transverse rows of scales which cross the lateral line; the scales are so arranged as to form rows which run obliquely downwards somewhat from before backwards, other rows which run more obliquely downwards and from behind forwards, and others,

which are not so distinct, which run straight from before backwards; it is the rows of the first kind which are counted. The number of these rows indicated by the letters L.l. is not so absolutely certain as the number of fin-rays in a fin, for the rows of scales are counted from the commencement of the lateral line to the base of the tail, and as the lateral line is actually continued to the very extremity of the tail, while the scales diminish in size gradually at the base of the tail until they get so small that the rows cannot be counted, there is, of course, no definite point where the counting ceases.

CHAPTER III.

SOLEA VULGARIS, Quensel.

[Plates I to V.]

Synonymy.

βούγλωσσος, Athen. vii, p. 288.

"Lingulaca," Varro and Plautus.

"Solea," Ovid, v. 124; Plin., ix, c. 16.

"Buglossus sive Solea," Rondeletius, xi, c. 11, p. 320, and other mediæval authors.

"La Sole," Rondelet, 1558, French edition, Lyons, p. 256.

"Pleuronectes, sp.," Artedi, 1734, *Genera*, p. 18, No. 6; *Species*, p. 60, No. 5; *Synonymia*, p. 32, No. 8.

"Pleuronectes solea," Lin., *Syst. Nat.*, 1, p. 457; Bloch, 1784, *Fische Deutschl.*, ii, p. 42, taf. 45; Lacépède, iv, p. 623; Donovan, 1808, *Brit. Fish.*, iii, pl. 52; Risso, 1810, *Ichth. Nice*, p. 307.

"Sole," Pennant, *Brit. Zool.*, iii, p. 203.

"La Sole," Duhamel, iii, sec. 9, p. 257, pl. 1.

"Solea vulgaris," Quensel, 1806, *Vet. Akad. Handl.*, p. 230; Risso, 1826, *Nat. Hist. Eur. Mér.*, iii, p. 247; Bonaparte, *Fauna Ital.*, iii, 26; Günther, 1862, *Brit. Mus. Catal.*, iv, p. 463; Moreau, 1881, *Poissons de la France*, p. 304; Francis Day, 1884, *Fish. Gt. Brit. and Ire.*, p. 39, pl. cvi.

	Males.			Females.			
Total length	16·9 cm. = $6\frac{5}{8}$ in.	26·4 cm. = $10\frac{3}{8}$ in.	33·2 cm. = $13\frac{1}{16}$ in.	17·6 cm. = $6\frac{15}{16}$ in.	19·4 cm.	35·6 cm. = 14 in.	38 cm. = 15 in.
Length / height	$3\frac{2}{7}$	$3\frac{1}{15}$	$3\frac{1}{5}$	$3\frac{2}{7}$	3	$3\frac{1}{9}$	$3\frac{2}{13}$
Length / head	$5\frac{1}{2}$	$5\frac{5}{6}$	$6\frac{1}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	$6\frac{1}{12}$	6
D.	90	83	86	86	83	81	87
A.	74	69	74	69	66	73	70
C.	21	20	21	20	21	22	20
Pt.	7	8	8	8	8	7 r. 8 l.	9
Pv.	5	5	5	5	5	5	5
L.l.	159	155	160	153	149	166	166
Vert.	—	50	48	—	—	50	48

A comparison of the above figures gives the following results. There are no constant sexual differences in any of the ten characters given in the table, except

that the females reach the larger size, nor any constant differences depending on size, although it is possible that a slight increase in the number of rows of scales takes place in individuals which grow very large. The largest individuals in the above table have the largest number of rows of scales. The number of pelvic fin-rays is constant, that of the pectoral rays, and of the caudal, nearly so. The number of vertebræ varies very slightly. The range of the numbers of the dorsal and anal fin-rays is considerable, in the above specimens 83 to 90, and 66 to 74, respectively The range for the lateral line scales is greater, namely, 149 to 166. In all these cases examination of a greater number of specimens would doubtless have extended the range.

Fins.—The dorsal fin commences a little in front of the dorsal eye, but behind the apex of the snout. The right pectoral is scarcely longer than the left and is contained two and a half times in the length of the head.

Eyes.—Longitudinal diameter of eye one-sixth the length of the head; scaled skin between the eyes equal in breadth to the longitudinal diameter of the eye; distance of dorsal eye from edge of the snout equal to the longitudinal diameter of the eye. Posterior edge of dorsal eye on a level with the middle of the ventral.

Nostrils.—On the right side both nostrils are close together immediately in front of the ventral eye and close to the edge of the upper lip. Both are tubular, the posterior a little the wider, the anterior the longer. On the left side the two nostrils are also thin walled tubes, the anterior being prominent and larger, the posterior quite obscure; the latter is about half an inch (in adult) above and behind the former.

Mouth.—Extends backwards to beneath the middle of the ventral eye: the teeth on the lower side are slender rods set close together in a broad curved patch in each jaw. The villi on the under side of the snout are really connected at the base by slight membranes which enclose depressions of the surface, but the latter are very small and the villi are therefore closely crowded together.

Scales.—On the right side extend over the whole surface of the head up to its very edges, on the lower side they decrease in size in the neighbourhood of the villi and disappear where these are fully developed. The villous area is bounded posteriorly by a straight transverse line running a short distance behind the angle of the mouth. One of the largest scales from the middle region of the right side of the body (Pl. XIV, 1) has sixteen radiating rows of spines, five spines in each of the middle rows.

The curved anterior portion of the lateral line is very distinct on the right side, and can be traced running parallel to the edge of the body right to the apex of the snout. On the lower side a similar curve exists, and in addition a line belonging to the same system which runs straight forwards from the origin of the former above the mouth, giving off transverse branches.

Colour.—The dead sole in the market generally appears to be of a uniform dull dark brown on the upper side, but closer examination shows that there are black blotches as well on the brown ground. During life the colours are much brighter,

and the markings much more conspicuous. Although the colours vary with the ground on which the animal rests, this variation is only in depth of tint; the markings are constant for the same individual, and vary but little in different individuals, they have therefore quite as much importance as a specific character as any other feature in the animal.

The markings, then, in the living fish consist of large dark blotches and small white spots on a yellowish-grey ground. The dark blotches, brown or black according to their intensity, are arranged symmetrically so as to form a definite pattern: the largest blotches are in three rows, one along the lateral line, one near the base of the dorsal, and one near that of the anal fin. Usually there are five or six of these blotches in each row, but in some specimens there may be as many as eight in one or more of the rows. The first blotch of the dorsal row is close behind the anterior curve of the lateral line, and the last near the base of the tail; the first of the central row is just above the end of the pectoral fin, and the first of the ventral series is at the base of the pelvic fin. The first and last in each series are always fainter and smaller, while those in the centre of the series are larger and more conspicuous. In each of the intervals between the blotches in each series is a lighter white spot, smaller and with a more definite outline than the dark blotches. Other white spots frequently appear around the dark blotches. Between the central row of blotches, and each of the external rows is another row of similar blotches of smaller size; these are closer together, nine or ten of them can be usually counted in each series, and in the intervals between them there are small white spots. These are the principal markings, but there are in addition narrow irregular branching streaks of a lighter brown extending from the edges of the dark blotches over the spaces between them; these streaks usually contain dark or black specks, but under certain conditions they are everywhere almost as dark as the blotches, and then the latter are connected together by an irregular network of black streaks. Outside the external series of blotches, between them and the bases of the dorsal and anal fins respectively, is a band free from markings where the ground colour is uniform and lighter than elsewhere. The dorsal and anal fins themselves exhibit three distinct longitudinal bands of colour; the basal third is dark, being densely sprinkled with minute black specks on a yellow ground, the middle portion is yellow without the black specks, while the extreme edge is colourless, the membrane between the rays being here transparent, while the skin over the extremities of the rays themselves is opaque white. The extreme dorsal and ventral edge of the tail fin are opaque white, the external portion of the tail, including the terminal half, is yellow, this portion being continuous with the light band which lies within the bases of the dorsal and anal fins; the internal and basal part of the tail is sprinkled with black like the basal part of the dorsal and anal fins. The right side of the head is coloured like the parts of the body-surface between the blotches, that is, with blacks specks connected by faint brown lines on a yellowish ground.

The pectoral fin has usually a black spot on its outer half, but very often this spot is only light brown, its intensity varying according to the action of light upon the animal.

When we examine still more minutely the elements of the coloration now described, we find that each of them is compound, made up of still smaller markings which have a definite relation to the scales. The scales are imbricated like the tiles on a roof, and the exposed portion of each, which projects backwards, has the shape of the sector of a circle. Except in the white spots, where the whole sector is opaque white, the basal angle of the sector is lightest in colour, and the colour deepens in intensity to the extreme border which is darkest. Even in the lightest part of the ground colour the border of each scale is distinctly defined by its brownish colour, while in the darkest part of the blotches and black specks the curved edge and the posterior half of the scale is black, while the anterior angle is light brown or even yellow.

The scales do not extend right up to the edge of the transparent cornea of the eyes, the skin bordering the cornea is smooth, and coloured green with brown specks, the iris is yellowish-grey marked with radiating brown lines. The pupil is black at its edges, but in the centre of it is a beautiful iridescent spot which dissection shows to belong not to the surface of the cornea, but to that of the crystalline lens.

This species, being abundant on both the shores of the Mediterranean and the Atlantic coasts of Europe, has been generally known since the earliest historical times. It is mentioned by some of the ancient historical writers as *βοὐγλωσσος* by the Greeks, and *lingulaca* or *solea* by the Romans. The former two names are taken from its resemblance in shape to the tongue, the latter from its resemblance to the sole of a shoe. Similar names are still in use in the various European languages: the Germans call it *zunge*, the tongue, and we call it the sole. In Italy it is called in some places *lingua* or *linguattola*, in others *sogliola*. The name tongue is also used sometimes for small soles at Billingsgate.

After the revival of learning in the sixteenth century, when the study of systematic natural history began to develop, the name Buglossus or Solea, borrowed from the ancients, was used for this fish by all naturalists up to the time of Artedi, that is up to the commencement of the eighteenth century.

Artedi, who died in 1734, placed all the flat fishes which had previously been usually grouped together by the mediæval ichthyologists, in one genus, *Pleuronectes*, a name first introduced by himself.

Linnæus, who edited Artedi's works, added little to the knowledge of fishes beyond applying binomial terms to the species defined by the latter. He named the sole *Pleuronectes solea*, in which he was followed by a number of his successors.

But it was soon found necessary to make the flat fishes not a single genus, but a family, classifying the diverse forms under various genera. This was in reality a return to the practice of the pre-Linnæan naturalists, the results of Artedi's accurate

distinctions and Linnæus' system of nomenclature being retained. The name *Solea vulgaris* was first used by Quensel, a Swedish zoologist, in 1806, and it has been generally employed since that time. The species has since then always formed the type of the genus, the number of species included with it varying in the systems of classification adopted by different ichthyologists.

CHAPTER IV.

SOLEA LASCARIS, Bonaparte

[Plate VI.]

Synonymy.

"Pleuronectes lascaris," Risso, 1810, *Ichthyologie de Nice*, p. 311.
"Solea lascaris," Risso, 1826, *Hist. Nat. de l'Eur. Mér.*, t. iii, p. 249.
"Solea nasuta," Nordm, in *Demid. Voy. Russ. Merid. Zool.*, iii, *Poissons*, Tab. 31.
"Solea lascaris," Bonaparte, 1841, *Fauna Italica*, t. iii, 27*, with 2 figures.
"Solea pegusa," Yarrell, 1829, *Zool. Journal*, vol. iv, p. 467, pl. 16.
"Lemon Sole," Yarrell, 1836, *Brit. Fishes*, first edition, vol. ii, p. 260.
"Solea aurantiaca," Günther, 1862, *Cat. Brit. Mus.*, vol. iv, p. 467.
"Solea lascaris," Moreau, 1881, *Poissons de la France*, t. iii, p. 307.
"Solea lascaris," Francis Day, 1884, *Fishes, Gt. Brit. and Ire.*, vol. ii, p. 42, pl. 107

	Male.	Females.		
Total length	17·2 cm. $6\frac{13}{16}$ in.	18·9 cm. $7\frac{7}{16}$ in.	19·2 cm. $7\frac{1}{2}$ in.	26·1 cm. $10\frac{5}{16}$ in.
Length / height	$2\frac{6}{6}$	$2\frac{14}{17}$	$2\frac{3}{4}$	$2\frac{17}{21}$
Length / head	$5\frac{4}{5}$	$5\frac{5}{6}$	$5\frac{2}{3}$	$5\frac{2}{3}$
D.	79	81	89	82
A.	67	67	70	70
C.	20	20	20	20
Pt.	9	9	8	9
Pv.	5	5	5	5
L.l.	125	125	123	119
Vert.	—	—	46	46

Of this species I have only been able to make a detailed examination of the four specimens whose numerical peculiarities are given in the above table.

Comparison of the above characters with those of *Solea vulgaris* shows that the present species is much broader in proportion to its length than the former, that the proportion of the length of the head to the total length is about the same, that the vertebræ are fewer in number, and the scales larger in proportion to the length of the body.

Fins.—The dorsal commences just a trifle farther forwards than in *S. vulgaris*, the base of the first ray being in line with the longitudinal diameter of the upper eye. The two pectorals are equal in length, and the length is contained two and a half times in the length of the head.

Eyes.—Dorsal eye half of its longitudinal diameter in front of the ventral, and more than its long diameter from the end of the snout; therefore not so near the edge as in *vulgaris*.

Nostrils.—Both nostrils on the right side close together immediately in front of the ventral eye, both tubular, but the anterior considerably the longer. On the left side the anterior nostril is very broad and dilated, its edges being reflected outwards. These edges are covered externally with the slender papillæ of the under surface of the snout. Internally there are a number of folds projecting from the inner surface of the nostril radially towards its centre, the ventral of these folds being thicker than the rest: the posterior nostril is tubular, narrow, and flaccid, and situated a short distance behind the upper part of the rim of the anterior.

Mouth and *Teeth* as in *vulgaris*. The villi of the under side of the snout are finer and even more closely crowded than in *vulgaris*; they are especially long and numerous round the edge of the dilated nostril. The villous area does not extend so far backwards as in *vulgaris*. The scales cover the whole right side of the head, as in *vulgaris*, but on the lower side they extend farther forwards above the nostrils, though lines of villi are developed along the transverse branches of the cephalic portion of the lateral line system. One of the scales from the middle region of the right side of the body has seventeen radiating rows of spines, six spines in each of the middle rows. (Pl. XIV, 4.)

The curved portion of the lateral line on the head on the right side is almost as distinct as in *vulgaris*; on the lower side the arrangement is the same as in that species.

Colour.—After death the colour is much lighter than that of *vulgaris*, being yellow-brown instead of dull brown; hence the name lemon sole by which the species is sometimes called. In life the ground colour is a brownish-yellow, and the markings consist of numerous small black specks scattered pretty uniformly over the whole surface. Careful examination shows that among these black specks, groups can be recognised which correspond in position with the black blotches of the common sole. In these groups the specks are somewhat larger and closer together than elsewhere. Thus the markings of the present species could be derived from those of *vulgaris* by taking away so much of the black of the blotches in the latter as to leave only a group of distinct specks. Among the specks are scattered other small spots of a light blue colour; these correspond to the white spots of *vulgaris*, but I have never seen them white. What was said of the relation of the colour to the scales in *vulgaris* applies here also; many of the scales are bright yellow at their bases. The colour of the fins resembles that in *vulgaris*; there is a black spot on the outer half of the pectoral. The eyes are coloured as in *vulgaris*.

The British form of *Solea*, which is distinguished from the others by the dilatation of the left nostril, was first observed by Yarrell, who described and figured it in the "Zoological Journal," Vol. IV, in 1829, under the name *Solea pegusa*. His description is so bad that it would be impossible to identify the species by its means with certainty, but his plate shows the distinguishing characters quite clearly. Yarrell considered his specimens to belong to the species *Pleuronectes pegusa* of Lacépède's "Histoire Naturelle des Poissons," Vol. IV, 1803, and with the *Pleuronectes pegusa* of Risso's "Ichthyologie de Nice," 1810, which is called *Monochirus pegusa* in the same author's "Hist. Nat. de l'Europe Méridionale." In the third edition of Yarrell's "British Fishes," Sir John Richardson identified this species as the *Pleuronectes nasutus* of Pallas' "Zoographia Rosso-Asiatica," 1811. But the *Pl. pegusa* of Lacépède is the *Solea ocellata* of Günther's Catalogue, the *Pleuronectes ocellatus* of Linnæus, the *Solea oculata* of Rondelet, a well-marked species in which the nostril is not dilated; and the *Monochirus pegusa* of Risso is another species of the Mediterranean which has no pectoral fin on the blind side, and in which also the left nostril is not dilated: it is the *Solea monochir* of Günther's Catalogue.

Yarrell's identification was therefore entirely incorrect, and Pallas' description of *Pl. nasutus* is so extremely vague that it is difficult to ascertain to what species it referred. The specimens described by Pallas by the name *nasutus* were taken in the Theodosian Gulf in the Black Sea. The *Solea ocellata* and *Solea monochir* both occur at Nice.

Dr. Günther, in his "Catalogue of the Fishes in the British Museum," Vol. IV, 1862, distinguishes four species of Solea in which the left nostril is dilated and flattened. The British form, called by Yarrell *Solea pegusa*, the lemon sole, or French sole, is described as distinct from any other known species, and is named by Dr. Günther, *Solea aurantiaca*. The second of the four species is the *Solea lascaris* of Risso, the third *Solea impar* of Bennett, and the fourth *Solea margaritifera* of Günther, another new species. I have examined myself the specimens in the collections of the British Museum, which Dr. Günther thus described in his Catalogue, and in many respects I cannot agree with him in his arrangement and identification of them.

Risso's original description of *Solea lascaris* is not very exact, and the small figure he gives is quite worthless; it would be impossible to identify the species from the figure. The numbers of fin-rays he gives are as follows:—

D. 85, A. 68, P. 7, V. 5, C. 15.

He says that the colour is "fauve tigré de noir, avec des reflets violets, parsemés de points grisâtres sur la surface droite." He says that the upper jaw covers the inferior in such a manner as to imitate the beak of a parroquet, and then continues: "Le dessous de la tête est orné de petits cils soyeux, blanchâtres, entourant un long tube qui répand une humeur glaireuse." Now it is difficult to understand how a naturalist could describe the dilated nostril of Yarrell's lemon sole as "un long tube," but as

Risso makes no mention of any nostril on the under side of the head of any other species of Pleuronectes, it is pretty evident that he was struck with a peculiar conspicuous nostril, such as exists in the English form we are considering.

Bonaparte gives a good description and two excellent coloured figures in his "Fauna Italica," 1832–41, of a species which he calls *Solea lascaris*, and which he identifies with the *Solea lascaris* of Risso's "Hist. Natur. de l'Europe Mér.," the *Pleuronectes lascaris* of the same author's "Ichthyologie de Nice." The fin formula given by Bonaparte is—

D. 78, A. 60, P. 8, V. 5, C. 19.

It will be seen that the formula given by Risso agrees perfectly with the numbers observed by myself in British specimens, and that Bonaparte's differs so little from the lowest numbers found by me that, considering the rest of his description and his figures, there can be no doubt that the British specimens are of the same species as those observed by him. I conclude, therefore, that Bonaparte was correct in his identification, and that the British species of sole, described above, is the *Solea lascaris* of Risso, more completely described by Bonaparte under the same name.

Dr. Günther identified the *Solea impar* of Bennett, of which he possessed only the original type specimen described by Bennett himself, with the *Solea lascaris* of Bonaparte. But, after carefully examining the specimen and the descriptions myself, I am unable to accept Dr. Günther's conclusion.

In the British Museum Catalogue a single specimen is identified as the *Solea lascaris* of Risso. The chief peculiarities in Dr. Günther's definition of this species are: the small size of the scales, the formula being Ll. 150; the narrowness of the body, the height being one-third of the total length; and the prolongation of the upper jaw, which is described as "produced into a longish lobe overhanging the lower." Of these characters only the last corresponds to anything in Risso's description; but I find that in my English specimens of the lemon sole, the upper jaw embraces the apex of the lower somewhat more than in the common sole, and that in the British Museum specimen the jaws do not differ to any appreciable extent in this respect from the English form. What Risso says on this point applies to the English specimens. Risso says nothing concerning the number of the scales nor of the proportion of breadth to length in his *lascaris*.

The specimen which Günther calls *Solea lascaris* came from Madeira; the specimen called *Solea impar* by Bennett came from the Atlantic coast of North Africa. Risso's *Solea lascaris* on the other hand, occurred at Nice, and Bonaparte's species is described as common at Venice, at Nice, and on the Roman shores. In the collections under Dr. Günther's charge there are specimens identified as *Solea aurantiaca* from Lisbon and from Nice. Thus specimens of the same species as the English specimens have been found at Nice, while the British Museum possesses no specimen identified with Risso's *lascaris*, or with Bonaparte's *lascaris* from any part of the Mediterranean.

I will now shortly consider the question of the identification of the actual specimens catalogued by Günther. In the single specimen he calls *lascaris* I could count only 133 rows of scales, a number not much larger than the maximum 125 found by me in the English form. As for its narrowness, it had been forced into a bottle much too narrow for it, and had in consequence been much compressed in breadth, so that I think it is scarcely possible to be certain about its proportions. I do not consider it to be specifically distinct from the *Solea lascaris* of Bonaparte.

Solea impar, Bennett, and *Solea margaritifera*, Günther, must for the present be considered distinct. They differ from English specimens of *Solea lascaris* in numerical characters and also in colour. Both of them possess the marking characteristic of *vulgaris*, that is to say, there are dark spots arranged as in *vulgaris*, not divided up into small specks as in *lascaris*. *Margaritifera* is further distinguished by the conspicuousness of the small white spots in the type specimen in spirit. It may be found in the future that English specimens of *S. lascaris* exhibit a range of variation which would include both these species.

Moreau, in his "Poissons de la France," 1881, also identifies the *Solea aurantiaca* of Günther with the *Solea lascaris* of Risso and Bonaparte, but he further includes the *Solea impar*, Bennett, in the same species, although it is not clear from his description whether he actually discovered by his own observation that the range of variation of *lascaris* included the characters of *impar*. Francis Day, in his "Fishes of Great Britain and Ireland," 1880–84, gives the same synonymy as Moreau.

CHAPTER V.

SOLEA VARIEGATA, Fleming (Donovan).

[Plate VII, Figs. 1 and 2.]

Synonymy.

"Pleuronectes variegatus," Donovan, 1808, *Nat. Hist. Brit. Fishes*, pl. 117
"Pleuronectes mangilli," Risso, 1810, *Ichth. Nice*, p. 310.
"Rhombus mangili," Risso, 1826, *Hist. Nat. Eur. Mér.*, p. 255.
"Variegated Sole," Yarrell, 1836, *Brit. Fishes*, first edition, p. 262.
"Monochirus variegatus," Thompson, 1839, *Ann. Nat. Hist.*, vol. ii, p. 404.
"Solea mangilii," Bonaparte, 1841, *Fauna Italica*, t. iii, 27**.
"Solea variegata," Fleming, *Brit. Animals*, p. 197; Günther, *Catal.*, iv, p. 469.
"Variegated Sole," Couch, *Fish. Brit. Isles*, iii, p. 203, pl. 177.
"Solea variegata," Günther, 1862, *Brit. Mus. Catal.*, vol. iv, p. 469.
"Microchirus variegatus," Moreau, 1821, *Poissons de la France*, t. iii, p. 317.
"Solea variegata," Francis Day, 1884, *Fishes Gt. Brit. and Ire.*, vol. ii, p. 43, pl. 103, fig. 1.

	Males.				Females.				
Total length	17·2 cm. $6\frac{3}{4}$ in.	17·9 cm. 7 in.	18·3 cm. $7\frac{1}{4}$ in.	19·1 cm. $7\frac{1}{2}$ in.	19·7 cm. $7\frac{3}{4}$ in.	19·9 cm. $7\frac{13}{16}$ in.	20 cm. $7\frac{7}{8}$ in.	21 cm. $8\frac{1}{2}$ in.	21 cm. $8\frac{1}{2}$ in.
$\frac{\text{Length}}{\text{height}}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{3}$	$3\frac{1}{2}$	$3\frac{1}{3}$	$3\frac{3}{7}$	$3\frac{1}{3}$
$\frac{\text{Length}}{\text{head}}$	$6\frac{1}{6}$	$6\frac{1}{6}$	$6\frac{1}{12}$	6	$6\frac{1}{6}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{5}$
D.	68	74	68	74	73	69	72	72	71
A.	53	54	52	58	55	55	57	56	54
C.	18	18	18	16	18	18	18	18	18
Pt.	4 r. 1 l.	5 r. 1 l.	4 r. 2 l.	4 r. 1 l.	4 r. 2 l.	4 r. 1 l.	4 r. 1 l.	5 r. 3 l.	4 r. 1 l.
Pv.	5	5	5	5	5	5	5	5	5
L.l.	89	93	90	92	88	89	89	104	87
Vert.	—	—	—	40	—	—	—	41	40

The above figures show that while the two preceding species cannot be separated by the range of variation of the numbers of fin-rays in the dorsal and anal fins, the

present species can be so separated from those two. The range for the dorsal fin-rays in the above specimens is 68–74. Dr. Günther in his Catalogue gives 63–73, Day's "British Fishes" gives 65–74: the total range recorded therefore is 63 to 74. Similarly for the anal fin-rays the range in the above table is 52–58; Günther gives 53–57; Day 55–58, therefore the range in my table is the greatest recorded. Day gives the number of caudal fin-rays as 15, evidently not counting the smaller external rays. Günther gives the scales of the lateral line as 85, Day as 85 to 90; the range in my specimens is 87–104. The number of vertebræ is here again very constant, and forms a good specific character, though it must be remembered that it is doubtful if it would serve to distinguish this species from all other known species of Solea. The proportion of breadth to length resembles that in *vulgaris*, and is therefore less than in *lascaris*, while the proportion of head to length is usually less than in the other two species, but does not form a marked specific character.

Fins.—The dorsal commences slightly farther forwards than in the two preceding species, the base of the first ray being actually nearer to the mouth than is the continuation of the longitudinal diameter of the dorsal eye. The right pectoral is much larger than the left, but much smaller than the pectoral of the preceding species: its length is contained $3\frac{1}{2}$ to $4\frac{3}{4}$ times in the length of the head. The left pectoral is a mere insignificant filament, never more than $\frac{1}{8}$ in. long, sometimes much smaller: it may contain one, two, or even three rudimentary fin-rays.

Eyes.—The dorsal is only $\frac{1}{3}$rd its own longitudinal diameter in front of the ventral, and $\frac{2}{3}$rds of the same length from the edge of the snout.

Nostrils.—The two on the right side are in the same position as in the preceding species, but the posterior is smaller, and the anterior a more elongated tube than in them. The two on the left side are situated as in *S. vulgaris*, but are smaller and less conspicuous.

Mouth is much less curved downwards than in the two preceding species, the anterior end of the cleft being slightly more dorsal than the angle of the cleft, while in the two previous species it is considerably more ventral: the anterior end of the cleft is in fact on the same longitudinal level as the lower border of the ventral eye, while in the other two species it is considerably ventral to that level. The snout is more truncated than in the other two species, the apex scarcely projecting beyond the anterior end of the mouth-cleft. Two patches of rod-like teeth, as in the other species, on the left side. The villi of the under side of the snout form short fringes at the edge of somewhat broad membranous folds of the skin, which have a reticulate arrangement enclosing quadrangular depressions of considerable size. This conspicuous reticulate arrangement of fringed membranes forms a distinct contrast to the closely crowded filaments in the two previous species (Pl. VII, 2).

The scales are absolutely broader than in any of the other British species, the breadth being almost equal to the length: they are also much larger in proportion to the size of the body than in either of the two preceding species, as is evident from

the number of lateral line scales given in the numerical table. A scale from the middle of the body (Pl. XIV, 3) has 26 rows of spines, the middle rows having 8 spines each.

The posterior vertical portion of the curve of the lateral line on the right side of the head can be detected with difficulty, but the anterior part parallel to the base of the dorsal fin is wanting altogether. The branches of the lateral line system on the left side of the head in the previous species are also invisible in *variegata*.

Colour.—The general colour is much brighter than that of either of the preceding species, being a distinctly reddish-brown with markings deepening to black. Of these markings the principal are five broad dark transverse bands, each of which terminates at either end in a large intensely black blotch situated partly on the side of the body, partly on the longitudinal fin. The first of these bands passes across just behind the pectoral fin, the others are at about equal distances, the last covering the ends of the dorsal and anal fins and the base of the tail. The central part of each band is only slightly darker than the neighbouring surface, but its anterior and posterior edges are usually very sharply defined. The darkening of the bands is produced by the presence of a thin black border at the edge of the scales, and the sudden extension of this black border over the whole scale produces the black blotch at each end of the band. Between the principal bands there are lighter areas which are again marked by one broad or two narrow secondary bands: these also terminate in black patches, which in this case are usually situated on the outer part of the fin and extend to its edge: these patches are smaller and less regular than those belonging to the principal bands. There is a single secondary band not very well defined passing over the operculum: the rest of the head is almost uniform in colour.

The anterior part of the tail, behind the last of the principal dark bands, is lighter than any other part of the body, its tint being yellow, while the rest of the tail is dark brown, the colour being here chiefly situated in the membrane between the rays. The tips of the dorsal and anal fin-rays are, as in the preceding species, opaque white. The brightness of the red tint in the coloration fades considerably after death, approximating more to grey.

What was said of the relation of the colour to the scales in the preceding species applies to this species also, but to a less degree; the extreme edge of every scale in the lighter parts is brown, but each scale is everywhere more uniform in colour than in *vulgaris* or *lascaris*.

This species is well marked, and has generally been recognised by ichthyologists since its first discovery. It was first distinguished in England by Donovan, who obtained a single specimen from the London market in 1807. He described and figured it in his "British Fishes" under the name *Pleuronectes variegatus* as a nondescript (new) species, although it has since been found that Duhamel had previously described it in his "Poissons de la France" under the name *Pole panachée*. Donovan's coloured figure is fairly good, but it represents the markings across the body as somewhat

irregular interrupted stripes, instead of regular dark bands. It is possible that in Donovan's specimen the markings were as he figured them, but I have never seen such a variety of colouring, and it is more probable that in the single dead specimen from the market he did not perceive the markings accurately.

The species was independently described as new by Risso in his "Ichth. de Nice": that his species is the same is evident from his accurate description of the colour and markings and some other characters. He gave it the name *Pleuronectes mangilli*, after the surname of one of his contemporaries. In his later work, the "Hist. Nat. de l'Europe Méridionale," he calls the species *Rhombus mangili*. He gives no figure.

Yarrell, in his first edition, gives a description and a woodcut from a specimen from Cornwall, but his figure looks as if it had been copied from Donovan's plate. Yarrell incorrectly identified the species with the *Solea lingula* of Rondelet, the *Linguatula* of Cuvier, a mistake which he afterwards corrected in his supplement.

Bonaparte gives an excellent description and a coloured figure of the species under the name *Solea mangilii*, identifying it with Risso's species. His figure beautifully shows the dark transverse bands terminating at either end in black blotches which extend on to the fins.

Günther in his Catalogue gave a complete and correct account of the synonymy of the species; his list of synonyms shows that the species has been described independently at least four times, first as the *Pole panachée* by Duhamel, then as *Pl. variegatus* by Donovan, as *Pl. microchirus* by Delaroche, and as *Pl. mangilli* by Risso.

Moreau and Day give good descriptions of the species. The former gives no figure; the figure of the latter is not good, it gives the markings very incorrectly.

CHAPTER VI.

SOLEA LUTEA, Bonaparte.

[Plate VII, Figs. 3 and 4.]

Synonymy.

"Solea parva sive lingula," Rondeletius, 1554, *De Piscibus Marinis*, xi, c. 15, p. 32, with fig.
"La petite Sole," Rondelet, 1558, French edition.
"Pleuronectes luteus," Risso, 1810, *Ichth. de Nice*, p. 312.
"Rhombus luteus," Risso, 1826, *Hist. Nat. Eur. Mér.*, t. iii, p. 257.
"Solea lutea," Bonaparte, 1841, *Fauna Italica*, t. iii, p. 28.
"Monochirus minutus," Parnell, 1837, *Mag. Zool. and Bot.*, vol. i, p. 527, pl. 16, No. 2.
"The Solenette," Yarrell, 1839, *Brit. Fishes*, first edit. Suppl., p. 36.
"Monochirus linguatulus," Thompson, 1839, *Ann. Nat. Hist.*, vol. ii, p. 405.
"Solea lutea," Günther, 1862, *Cat. Brit. Mus.*, vol. iv, p. 469.
"Solea minuta," Günther, 1862, *ibid.*, p. 470.

	Sex ?	Male.	Female.	
Total length	5·2 cm. $2\frac{1}{16}$ in.	11·6 cm. $4\frac{9}{16}$ in.	7·3 cm. $2\frac{7}{8}$ in.	11·1 cm. $4\frac{3}{8}$ in.
$\frac{\text{Length}}{\text{height}}$	$3\frac{1}{6}$	$3\frac{2}{5}$	$3\frac{1}{2}$	$3\frac{1}{10}$
$\frac{\text{Length}}{\text{head}}$	$4\frac{3}{4}$	$5\frac{1}{4}$	5	$5\frac{1}{10}$
D.	73	77	73	69
A.	59	63	53	55
C.	16	18	16	18
Pt.	2 r. 1 l.	3 r. 1 l.	4 r. 1 l.	4 r. 1 l.
Pv.	5	5	5 r. 3 l.	5
L.l.	—	68	62	66
Vert.	—	—	—	37

The above table includes the characters of only a very small number of specimens, as I have not had an opportunity of examining more. The measurements of the total length show that this is the smallest species of the five. The head is longer in

proportion to the total length than in any of the other species; the proportion of greatest breadth to length is about the same as in *vulgaris* and *variegata*. But the body is considerably narrower towards the tail than in either of the other species. The range for the dorsal fin-rays in the above specimens is 69–77; Day gives 65–72. The range of number for the anal fin-rays in the above table is 53–63; Day gives 50 to 56. Day gives the lateral line scales as 72; the range in my specimens was 62 to 68.

Fins.—The dorsal fin commences nearer to the mouth than in any of the other species; the base of the first ray being on the very apex of the snout, on a level longitudinally with the upper border of the ventral eye. The pectorals are as in *variegata* rudimentary; the right is contained about $4\frac{1}{2}$ times in the length of the head; the left is extremely minute.

Eyes.—The dorsal is one-half its longitudinal diameter in front of the ventral and less than its diameter from the edge of the snout; they are very close together, the distance between them equal to half the longitudinal diameter of either.

Nostrils on the right side in their usual position, the posterior short and small, the anterior tubular and long; on the left side similar to those of *variegata*.

Mouth strongly curved downwards as in *vulgaris*; snout rounded as in that species.

The villi on the lower side the snout are arranged in the same manner as in *variegata*.

The scales absolutely are smaller than in either of the other species, though, as shown by the number of scales in the lateral line, they are in proportion to the length of the body larger than in the other species; and they are not so broad in proportion to their length as in *variegata*. One of the scales from the middle of the body has 21 rows of spines, 4 spines in each of the middle rows (Pl. XIV, 5).

No branches of the lateral line are visible externally on either side of the head.

Colour.—It is curious that, although in the character of its pectoral fins and of the villi of the lower side of the snout, this species closely resembles *variegata*, its markings are almost the same as those of *vulgaris*. In other words, there is here no correlation between the marking and other characters.

The ground colour of the right side during life is a dull reddish-brown. On this ground there are dark brown spots arranged as in *vulgaris*; there are three principal longitudinal rows of these, of which the central row contains usually five spots, the dorsal and ventral rows seven or eight. Alternating with the brown spots are light blue ones representing the white spots of *vulgaris*. There are also two intermediate longitudinal rows of dark spots. But the markings of the dorsal and anal fins differ considerably from those of *vulgaris*; these fins show no longitudinal bands of colour, but numerous narrow transverse stripes, each sixth or seventh ray being coloured a deep black; the rest of these fins has a yellowish colour which is deepest towards the base of the fins. The anterior part of the head is free from spots, the tail has a little black at its middle third.

This species was first recognised as distinct in Britain by Parnell, who described it in the "Magazine of Zoology and Botany," Vol. I, 1837, under the name *Monochirus minutus*. He believed that it had never been described before, and therefore gave it the name *minutus*, placing it in Cuvier's sub-genus *Monochirus*. He gives a figure of it, and mentions as its specific character that every sixth or seventh ray of the dorsal and ventral fin is black; he obtained his specimens at Brixham from the trawlers. W. Thompson in the "Annals of Natural History," Vol. II, 1839, identified Parnell's species *minutus* with that mentioned by Cuvier in the "Règne Animal," under the name *Linguatula*, which is the *Solea parva sive lingula* of Rondelet. Cuvier defines the *Monochires* as those specimens of Solea in which the pectorals are minute, the left being either very minute or altogether wanting.

I have consulted a French translation of Rondelet's original Latin work; this translation is dated "Lion" (Lyons), 1558. The names here given are *La petite Sole*, and *Solea lingula*, and though no characteristic specific features are mentioned in the description, the figure given agrees very well in shape with specimens of the present species; this figure shows the left side of the fish.

Yarrell introduced a figure and description of Parnell's *Monochirus minutus* into his supplement to the first edition of his "British Fishes," not having been acquainted with the species when he published the book.

Parnell's species was described as distinct by Dr. Günther in the British Museum Catalogue, under the name *Solea minuta* from two specimens, one, a dried skin, from Yarrell's collection, the other, stuffed and dried, from Brixham.

Moreau, in his "Poissons de la France," 1881, in describing *Microchirus luteus*, the *Solea lutea* of Bonaparte, suggests by means of a note of interrogation that *Solea minuta* is a synonym of that species, and Francis Day, in his "Fishes of Great Britain and Ireland," states without reservation that the two species are identical.

Dr. Günther in his Catalogue describes one specimen of Bonaparte's *Solea lutea*. He has informed me that he now considers the two species to be identical, and after examination of English specimens and Mediterranean specimens of *lutea* at the British Museum, and comparing them with the various descriptions, I have no doubt myself that *lutea* and *minuta* are the same species.

This species was first described by Risso, in his "Ichthyologie de Nice," under the name *Pleuronectes luteus*, and his description is sufficiently accurate for its identification. The same author, in his "Histoire Naturel de l'Europe Méridionale," placed the species in the genus *Rhombus*, calling it *Rhombus luteus*. Bonaparte, in his "Fauna Italica," gives an excellent description, and two very good coloured figures. He describes the colour of the body, apart from the fins, as a uniform golden yellow without spots, but in Mediterranean specimens in the British Museum I found the markings which I have described above in English specimens.

CHAPTER VII.

SOLEA GREENII, Günther.

"Solea Greenii," Günther, 1889, *Ann. Mag. Nat. Hist.*, vol. iv, No. 24.

Sex, female. Total length, 19 cm. ($7\frac{7}{16}$ in.). $\frac{\text{Length}}{\text{height}}$ = over $3\frac{1}{3}$. $\frac{\text{Length}}{\text{head}} = 6\frac{1}{8}$.

D. 81. A. 67. C. 19. Pt. 4 r. 2 l. Pv. 5. Ll. 138.

The above are the characters of a single specimen obtained by Mr. Bourne, Director of the Plymouth Laboratory, by the trawl on board H.M.S. "Research," on July 13, 1889, in long. 49° 5′ N., lat. 11° 14′ W., at a depth of 217 fathoms.

The characters of the species are, as Dr. Günther points out, intermediate between those of *vulgaris* and *variegata*. The filaments on the under side of the head are uniformly distributed as in *vulgaris*, but there is a series of transverse rows of such filaments along the whole length of the lateral line on the lower side, a character I have not seen in any other species. The pectorals are rudimentary as in *variegata*. The cephalic curve of the lateral line runs backwards before turning forwards. In colour the upper side is an almost uniform brownish-grey in spirit; but there are also dark blotches or large spots; there are six of these along the dorsal edge of the body and five along the ventral; also two along the lateral line posteriorly; these two with two dorsal and two ventral spots form two almost continuous transverse bands; another interesting transition from *vulgaris* to *variegata*. The outer half of the longitudinal fins has also a good deal of black pigment.

The ground where Mr. Bourne's specimen was taken was a fine grey sand containing Foraminifera. Mr. Green also obtained only a single specimen from a depth of 150 fms. 47 miles west of Bull Rock off Balinskellys Bay.

Thus this species lives just beyond the 100-fathom line in that part of the Atlantic which lies S.W. of Ireland.

PART II.

MORPHOLOGICAL.

CHAPTER I.

THE OSSEOUS SKELETON.

The whole body of the sole is covered by the skin, which as everyone knows is so slightly attached to the parts beneath it that it can be stripped off as a definite continuous membrane. Beneath it is found the flesh, which consists of the muscles, by the contraction of which all the movements of the fish are produced. The muscles are attached to the bones which together form the skeleton. In the middle region of the body on the ventral side is a cavity with smooth walls, within which are contained the entrails, or viscera, consisting of the organs of digestion, excretion, and reproduction. The principal organ of digestion is the digestive tube which leads from the mouth and after various convolutions opens to the exterior again at the vent or anus. The organs of respiration or gills are fringes supported on rods between which are slits or clefts by which the cavity of the throat opens on each side into a gill chamber. Each gill chamber again opens by a single aperture to the exterior. The blood vessels ramify in the substance of all the organs now mentioned, but the heart which keeps the blood moving in circulation is contained in a special cavity which is separate from that containing the viscera. The skin and the membrane lining the digestive tube become continuous with one another at the mouth and anus, and at the gill-clefts. The nerves also ramify in the substance of the muscles and other organs, but, excepting the sympathetic system, they all radiate from the brain and spinal cord which are contained in a chamber on the dorsal side of the skeleton, the brain being contained in the cavity of the skull, the spinal cord being enclosed by a series of arches formed by processes of the spine. Some of the nerves convey the impressions received by the senses to the brain, and may be regarded as proceeding from the sense organs to the brain; the principal sense organs are the skin, the eyes, the ears, and the olfactory organs. The other nerves conduct impulses from the brain and spinal cord to the muscles and other organs causing the former to contract and regulating the functions of the latter.

The structure and relations of these various organs can be made most easily intelligible by describing the skeleton first.

The Skull.—The central part of the skeleton consists of the skull and the vertebral column, the latter being composed of a longitudinal series of distinct bones, the

vertebræ: the skull here means the bony structure which contains the brain, and supports the eyes, ears, and olfactory organs, and which remains as a united whole when the soft parts of the head of the fish are removed by boiling or otherwise. The form of the skull is shown by four drawings of it on Plate XI (Figs. 5–8). It consists of two main portions. The posterior and larger portion has a somewhat cylindrical shape, and encloses a cavity in which the brain lies in the entire fish, this is the cranial portion; the anterior or facial portion does not enclose a cavity, but may be said to consist of three separate processes from the brain-case which unite together at their anterior ends. One of these processes is (apparently) on the right side of the head of the fish and separates the eyes from one another; it may be called the interorbital septum, the not very definite concavities on either side of it in which the eyes lie being the orbits.

If the skull is placed in the position it occupies when the entire fish is held vertically upright on its ventral edge, that is in the same position in which a symmetrical fish swims, the cranial portion of the skull will be seen to be almost perfectly symmetrical while no symmetry is visible in the facial portion. Comparing the cranial portion with the corresponding part of the skull of a symmetrical fish, we can recognise in its walls the same bones as in the latter, the walls being made up of these bones firmly united at their edges. These edges are usually irregularly toothed so as to fit into each other, and the lines of junction are called sutures. The sutures can be traced out with care in the entire cranium, but where they are obscure the exact limits of the component bones can be found by boiling the skull and pulling the separate bones away from one another. The outlines of these bones are indicated on the figures of the skull. The auditory organs in the entire fish are situated within the convex side walls of the cranial portion, and the bones of this part have names with the suffix "otic," implying their relation to the ear.

The back of the cranial portion is called in all vertebrates the occiput and the bones of this part occipital bones. In this wall of the cranium is a large circular aperture, the occipital foramen, through which the spinal cord is continued forwards into the brain. Below the occipital foramen is a solid bone with a conical depression in its posterior surface, this is the *basi-occipital*, and the depression marks the place where the first vertebra is attached to the skull. At the sides of the occipital foramen inferiorly are the two *ex-occipital* bones, ex.o., one on each side. Above these, reaching to the upper edge of the foramen, are two large somewhat convex bones, the *epiotics*, ep.o. On the dorsal surface of the skull there is in the centre a large median flat bone, the *supra-occipital*, s.o., which in many vertebrate skulls extends to the edge of the occipital foramen, but is here separated from it by the epiotics. On either side of the supra-occipital is a *parietal* bone, pa. In either lateral wall of the cranium, adjoining the edges of the ex-occipital, epiotic, and parietal, there is a somewhat large bone having a rugged process projecting outwards; this is the *pterotic* bone, pt.o. In front of this is a slightly smaller square bone, the *sphenotic*, sp.o. Between the pterotic

and the basi-occipital is a small square bone, the *opisthotic*, op.o., and in front of this below the sphenotic is the *prootic*, pr.o.

Adjoining the edges of both prootics and sphenotics, and attached behind to the basi-occipital, is an elongated keeled bone which projects forwards to form the ventral process of the facial portion of the skull: this is the *parasphenoid*, pa.s; its posterior portion forms the anterior part of the floor of the cranium. Attached to the ventral surface of the parasphenoid is a bone which is elongated dorsally and projects ventrally into a cylindrical knob; this is the *vomer*, vo. The interorbital septum is formed by the anterior processes of two bones whose flat posterior portions are nearly symmetrical and form the anterior part of the roof of the cranium, attached behind to the edges of the supra-occipital and parietals. These are the *frontal* bones, r.f., l.f. These bones are, as compared with the corresponding bones of the skull of a symmetrical fish, the most distorted of all the bones in the skull of the sole. In a symmetrical fish the frontal bones are perfectly symmetrical, and their anterior parts lie above and between the symmetrically placed eyes. In the sole also their anterior processes are between the orbits, but have been twisted round through an angle of 90°, so that the middle line of the dorsal surface of the cranium when produced forwards does not pass between the frontal bones, but a line drawn in a longitudinal direction over the right surface of the cranium, across the pteroic and sphenotic bones does pass between their anterior processes. This shows that the dorsal eye of the sole is really the left eye, and that the eyes and orbits with the interorbital septum have, as compared with those of a symmetrical fish, been twisted round through an angle of 90° while the cranial portion of the skull remained stationary. Connecting the inferior process formed by the parasphenoid and vomer with the interorbital septum anteriorly is a single bone having a somewhat hooked process in front—the *mesethmoid*, mes.e. Attached to the mesethmoid posteriorly on the left side, and joined also to the parasphenoid, is a large flat bone concave towards the right, the left *ectethmoid*, ect.e. A posterior process of this bone unites with an anterior process of the left sphenotic to form the third process of the facial region of the skull. The right ectethmoid is a small ring-shaped bone attached ventrally to the anterior end of the frontals and to the mesethmoid.

Between the origins of the three facial processes the cranial cavity opens anteriorly by a wide aperture. There is a large round foramen in the left ectethmoid, leading from the left orbit to the external surface of the facial part of the skull. On the upper surface of the cranial portion there is a small foramen in the flat posterior portion of each frontal bone, the left foramen being larger than the right. At the anterior and inferior edge of each sphenotic bone there is a considerable indentation, which, with a corresponding indentation in the edge of the parasphenoid, forms a large foramen, the sphenotic foramen. That of the left side is twice as large as that of the right, and in front of the former are two small foramina which are absent on the right side. Through each prootic bone is a smaller foramen, the prootic foramen; the left of these

is a little larger than the right. In the posterior part of each opisthotic bone is a minute opisthotic foramen. In each ex-occipital there is a considerable foramen directed downwards, and behind this a minute foramen directed outwards.

It now remains to call attention to the form of the outer surface of the skull. The pterotic process projecting outwards from the pterotic bone has already been mentioned. A similar but longer and flatter process projects from the sphenotic bone above the sphenotic foramen; these processes serve for the attachment of muscles. Below these two processes are two smooth depressions in which are articulated the two heads of the hyomandibular, a bone which is connected with the jaws and branchial apparatus. In the centre of the supra-occipital bone is a somewhat elongated crest. At each side of the dorsal surface of the skull posteriorly is another crest longitudinally directed, formed partly from the pterotic, partly from the parietal bone: this may be called the parietal crest; the one on the right is larger than that on the left. These crests also serve for the attachment of muscles. At the anterior part of the basi-occipital bone are a pair of conical prominences with their broad bases downwards: these are continuous with one another in the median plane. The left ectethmoid bone sends off a curved process towards the right side.

The Vertebral Column.—Any one of the vertebræ from the middle third of the spine consists of a somewhat cylindrical central mass, the centrum, and two elongated processes or spines, a dorsal and a ventral. The centrum has the form of two truncated hollow cones placed with their narrower ends towards each other and united together by a solid disc. The conical hollow at the anterior and posterior surfaces of each centrum with the corresponding hollows of the adjacent vertebræ, enclose cavities which are filled by an elastic gelatinous tissue. The lateral depressions at the right and left sides of the centrum are each divided by a longitudinal ridge of bone. The dorsal spine really consists of two hollow bony tubes which diverge at their bases, where they are united with the centrum towards the anterior edge of its dorsal surface, and which are united firmly together in the median plane of the fish's body for the greater part of their length. The diverging legs of the spine form a pointed arch, and through the series of these arches runs the spinal cord, which is thus protected from pressure by the bony arches. The leg of the spine on each side of the vertebra is expanded longitudinally where it joins the centrum, and in this expanded part are two foramina, through which the ventral and dorsal roots of a spinal nerve pass. The ventral spine of the vertebra has a similar structure, but the arch between its legs is larger, and through the series of these arches run blood vessels. There are 50 vertebræ altogether, and the 11th to the 50th have the structure now described. The dorsal and ventral processes in all these are very long, four to five times as long as the centrum. In the first of these vertebræ the spines are almost at right angles to the centrum, but towards the posterior end they slope more and more backwards. The spines increase in length slightly towards the centre of this region, and again decrease slightly at the posterior end. The centra become longer and narrower

towards the posterior end. Behind the last of these vertebræ are bones which terminate the vertebral column: these consist of a central fan-shaped bone, the anterior end of which is shaped like the anterior part of a vertebra, and is connected with the posterior face of the last vertebra by membrane, and two other flat bones, dorsal and ventral to the central one. The central bone expands posteriorly in the median plane of the body into a triangular plate, which is partially divided by radiating furrows into a number of rods. These rods are known from their development to represent the ventral spines of a number of vertebræ fused together into the fan-shaped bone. The flat bones dorsal and ventral to the fan-shaped bone are similarly divided, but are much narrower: these are obviously also dorsal and ventral spines of the more anterior of the vertebræ represented by the fan-shaped bone. The rays of the caudal fin articulate with the ends of these rods (Pl. X).

The ten anterior vertebræ differ considerably from the posterior 40. All of them have dorsal spines except the first: these spines resemble those of the vertebræ already described, except that they become thicker and shorter and more inclined forwards towards the anterior end. The dorsal spine of the second vertebra leans forward so much that it is in contact with the posterior face of the skull. The fifth to the tenth vertebræ have ventral spines also, but these are of rapidly decreasing length from the tenth to the fifth, and are also much inclined backwards. The first four vertebræ have no ventral spines. The second to the eighth vertebræ, seven in all, bear very slender short ribs which are not processes of the vertebræ, but separate bones which articulate with the centra at the upper side of their lateral ridges. The first vertebra is rudimentary: its centrum is very narrow antero-posteriorly, and it has two small dorsal processes which lie along the front edge of the base of the dorsal processes of the second vertebra, but do not unite to form a spine.

The centra of all these vertebræ are united together in the following way. The posterior face of each vertebra has, as we have seen, a conical depression or cavity: the rim of this cavity is united firmly to the corresponding rim on the anterior face of the succeeding vertebra by strong tough membrane, which is continued over the surface of the vertebræ, which is in fact part of the periosteal membrane. The closed cavities formed by the juxtaposition of the conical depressions are filled by a firm elastic gelatinous tissue which forms so many elastic pads between the centra. The connection of the ex-occipital bone of the skull with the first vertebra is of the same kind as that between adjacent vertebræ.

Closely connected with the vertebral column is the system of bones which forms the framework and support of the median fins. Placed like the vertebral spines in the median plane of the body and extending outwards from the ends of those spines are a great number of bones shaped somewhat like paddles. These are the *interspinous bones*. Each consists of a long slender shaft and a broad head expanded in the median plane They are placed with their shafts towards the vertebræ, their heads projecting outwards. The ends of the shafts lie alongside the ends of the spines of the vertebræ

in the intervals between the spines, hence the name of these bones. There are usually two interspinous bones between two adjacent vertebral spines, never more than two, but in many cases only one: one interspinous bone, in Fig. 1 on Pl. X, has two shafts to a single head, the end of a vertebral spine lying between the two shafts. In the middle region of the body each interspinous bone has a small wing-like expansion on each side of the shaft just below the head. On the dorsal side the interspinous bones are perpendicular to the vertebral column at about one-fourth of the whole length from the anterior end of the body: from this region to the tail they slope more and more backwards; from this region forwards they slope more and more forwards. In front of the dorsal spine of the second vertebra there are three short stout interspinous bones whose inner ends lie close to the middle dorsal line of the cranial portion of the skull. In front of these is a large curved spine-shaped bone pointed at its outer end, stout and blunt at its inner, which curves forwards almost parallel to the axis of the skull. To the dorsal side of this bone are attached two short interspinous bones.

On the ventral side the interspinous bone in front of the ventral spine of the eleventh vertebra is almost perpendicular to the vertebral column: from this point to the tail region the interspinous bones slope more and more towards the posterior end. In front of the same interspinous bone there is one other free interspinous bone slightly inclined forwards, and in front of this is a stout curved cylindrical bone, which terminates the series anteriorly and forms the posterior boundary in the median plane of the main body-cavity of the fish. This cylindrical bone bears four shortened interspinous bones which are inclined forwards and are successively shorter and shorter, the most anterior being merely a small head without a shaft.

The fin-rays of the dorsal and ventral median fins, of the dorsal fin and anal fin as they are usually termed, are not articulated directly with the outer ends or "heads" of the interspinous bones: to these heads are attached a series of nodules of cartilage, elongated from before backwards, and somewhat cylindrical in shape. Except in a certain region each of these nodules is situated between two adjacent heads of interspinous bones, attached to both of them. The region excepted is the anterior part of the dorsal series, where one nodule is attached separately to each head.

The fin-rays have the following structure. Each ray is compound and constructed somewhat in the same fashion as a vertebral spine. It consists of a right and left half, which are separate and divergent at their inner ends, attached together in the median plane of the fish for the outer seven-eighths of their length. The divergent ends embrace one of the cartilaginous nodules previously described, bestriding it as a man bestrides a saddle, and are attached to it by fibrous membrane in this position. One of the halves of the fin-ray thus belongs to the right or coloured side of the fin, the other to the left or white side. In consequence of the mode of attachment described, the fin-ray can only move on the cartilaginous nodule backwards and forwards: as a matter of fact its motion is limited between a position in which it is perpendicular to the longitudinal axis of the fish, and a position in which it lies inclined backwards from its attached

base, and almost parallel to the axis of the fish. The outer part of the fin-ray formed of the two united lateral halves bifurcates in an antero-posterior direction into two divergent branches. Thus the outer half of the fin-ray consists of two diverging branches both in the plane of the fin, one anterior and one posterior, but *each* of these is made up of two lateral halves glued as it were together lengthwise. Thus if a fin-ray is separated, and a knife passed between the diverging right and left legs of the ray, the whole ray can be easily divided into a right half ray and a left half ray, and *each* of these is forked at its outer half length into two branches. The basal portion of the fin ray is solid, but the outer five-sixths, including the two forked branches, consist of a series of short cylindrical bony pieces united by flexible membrane. Thus the outer part of the fin-ray resembles somewhat the series of vertebral centra on a small scale and without the spines, if we suppose the series of centra after being single for a certain length to branch into two series having the same structure.

The tail fin-rays resemble those of the dorsal and anal fins in general structure, but are more branched: in them each of the two original branches divides again into two, and some of these again into two: the branching of the ray is always dichotomous, that is, a branch when it divides splits only into two smaller branches, but of the four secondary branches all do not always divide: thus the fin-ray terminates in seven or eight branches spread out like a fan. The caudal fin-rays are not in connection with either interspinous bones or cartilaginous nodules, but are articulated directly to the terminal bones of the vertebral column, and to the spines of the last vertebra.

The skeleton of the paired fins is closely related to that of the branchial region and will be described in connection with it.

The Jaws and Branchial Arches.

We have now to consider the bones of the jaws and branchial arches, and other bones connected with the skull. The more superficial of these bones are shown in Figs. 1 and 2, Pl. XI. The bones of the right side, Fig. 1, differ considerably in size from those on the left, although in their relations the bones of the two sides correspond to one another. The bones of the right side are as follows. The two sockets in the side of the cranial portion of the skull, in the pterotic and sphenotic bones, contain the two rounded heads of a flat elongated bone which extends downwards and somewhat forwards. This is the *hyomandibular*, hm. To the lower end of this bone is attached a system of flat bones which projects horizontally forwards into a smooth knob with which the lower jaw is articulated, and sends off upwards and forwards a flat band of bone, the end of which is again attached to the skull at the side of the vomerine projection. At the posterior border of the hyomandibular and the system of bones just mentioned is a crescent-shaped bone, which is firmly attached to the others and acts like a splint, binding them rigidly together. This is the *preopercular*, po. The separate bones of the system connected with the lower end of the hyomandibular

are as follows. Directly attached to the end of the hyomandibular is seen the end of a bone which passes downwards beneath the preoperculum out of sight, and is connected with the system of branchial arches which occupy a deeper position. This is the *stylohyal*. Anterior to this is a flat bone which projects into the quadrate in its under surface, this is the *symplectic*, s. Dorsal to this is a flat somewhat concave bone with a triangular outline, the *metapterygoid*, mt. The triangular bone, which is at the anterior end of the series, and which supplies the rounded head to which the lower jaw or mandible, m., is articulated, is the *quadrate*, q. Running upwards from the quadrate dorsally are a pair of splinter-like bones, the anterior of which is the *pterygoid*, pt., and the posterior the *mesopterygoid*, ms. Connecting these with the skull at the side of the vomerine process is the *palatine*, pa. It will be seen that all these bones are somewhat larger on the left side, Fig. 2, than on the right, Fig. 1. The superiority is especially well marked in the pterygo-palatine bar, which is broad and strong on the right, narrow and delicate on the left.

Attached to the posterior edge of the hyomandibular and preopercular is the operculum, which is chiefly composed of the three bones, o., io., so.: these are the *opercular*, o., which is articulated to a knob projecting downwards on the posterior side of the head of the hyomandibular, the *interopercular*, i.o., and the *sub-opercular*, s.o., which are only held in their places by the fibrous tissue of the operculum. The lower jaw is called the mandible, which consists of three bones, the *articular*, *angular*, and *dentary*, fitted and firmly united together: the upper jaw consists of two bones, the *maxilla*, x, and the *premaxilla*, p.x. All these bones are much smaller on the right or upper side of the head than on the left or lower; this is especially true of the maxilla and premaxilla which, as the figures show, are almost rudimentary on the right side, and very large on the left. On the left side the maxilla is entirely excluded from the edge of the lip; on the right side its posterior process forms part of that edge. The mandible on the right side has the form of an elongated bar, on the left side it is a broad triangular stout plate, the dorsal edge of which is strongly convex and bears a patch of rod-like teeth, biting against a concave larger patch of similar teeth in the premaxilla. On the left side the end of the premaxilla articulates with a knob on the mandible, an arrangement which makes the bite much more effective; on the right side there is no such articulation. The two mandibles are firmly united together anteriorly in what is called the symphysis of the mandibles. The anterior ends of the maxillæ and premaxillæ are all firmly united together and to the lower side of the mesethmoid bone by fibrous membrane.

If we now dissect away all the bones above described except the hyomandibular, we find the bones of the branchial apparatus lying beneath them as shown in Plate XI, Fig. 3, from the right side. The gills themselves are vascular fringes which project outwards and backwards from a series of bars; between these are the clefts by which the water passes from the cavity of the throat to the gill chamber and so to the exterior. These bars are called the branchial arches, from their curved shape, and each bar is

supported by a series of bones called a (bony) branchial arch. The first of these arches is different from the rest, and is called the hyoid arch. It is attached to the end of the hyomandibular, and consists of, 1st, the small cylindrical bone, marked 2 in the figure, and called *stylo-hyal;* next, two broad stout bones placed end to end, 3 and c.h. in the figure, the *epi-hyal* and *cerato-hyal;* and finally, two cubical bones placed side by side, the *hypo-hyals*, h.h. Between the hypo-hyals of the opposite sides is inserted a bone which is flattened in the median plane of the fish's body: this is usually called the 1st *basi-branchial*, although in the sole it is connected only with the bones of the hyoid arch. Above it is a cylindrical bone called the *basi-hyal* or *entoglossal*, b.h.

Attached to the lower edge of the epi- and cerato-hyals are a series of long bones like curved spines, 3 to the epi-hyal, and 4 to the cerato-hyal. These are the *branchiostegal rays*, and they support a curved membrane which extends inwards from the inside of the lower edge of the operculum, and in ordinary respiration closes the lower part of the opercular aperture.

The 1st branchial arch is composed of a chain of bones of which the most dorsal attached to the side of the keel of the parasphenoid bone is the *pharyngo-branchial*, 8, next to this is the *epi-branchial*, 9: these two are directed downwards and outwards, but the *cerato-branchial*, c.b. 1, which succeeds, passes inwards and forwards; it is followed by the *hypo-branchial*, which is joined to the median 2nd basi-branchial, b.b. 2. The other arches, four in number, exhibit a similar plan of structure, but the last is much reduced. The pharyngo-branchials of the 2nd, 3rd, and 4th arches are not styliform, like that of the first, but are broad and flat; the 3rd and 4th are fused together, the 2nd is united to them, and all three bear teeth on their lower surfaces and form together the *upper pharyngeal* bone. The second hypo-branchial is articulated with the third basi-branchial, and the third hypo-branchial comes into slight connection with the posterior end of the same median bone. The two hypo-branchials of the fourth pair of arches are fused together to form a rhomboidal cartilage in the middle line behind the third basi-branchial. The fifth arch is represented only by a cerato-branchial on each side, which meets its fellow in the middle line; these two bones bear teeth on their upper surface, and being situated in the ventral wall of the throat they bite against the upper pharyngeal teeth, forming a second masticatory apparatus; these bones of the fifth arch are usually called the *lower pharyngeals*. The relations of the hyoid and branchial arches of the opposite sides are shown in Plate XI, Fig. 4 where they are seen spread out with their internal surfaces upwards.

The pectoral and pelvic fins on each side are attached to the posterior border of a bony arch which extends from the back of the skull downwards, curving first backwards and then forwards, and meeting its fellow of the opposite side at the ventral edge of the body. This bony arch forms the posterior border of the opercular cleft. It consists of the following bones: a *post-temporal*, 25, Fig. 3, which is forked anteriorly and attached by membrane to the posterior wall of the skull, the upper branch of the fork being connected with the epiotic, the lower with the opisthotic; a *supra-clavicle*, 26, an

elongated bone joined on to the lower end of the post-temporal, a *clavicle*, 27, which curves forwards, and is shaped like a trough the cavity of which is posterior, the trough being V-shaped in section. The clavicle is connected at its lower end, in the median ventral line, with its fellow of the opposite side.

The pectoral fin is supported by a flat basal plate attached within the upper part of the trough of the clavicle; this plate consists of two bones united by cartilage; the upper of these, 29, is the *scapula;* the lower, 30, the *coracoid.* The pectoral fin-rays are articulated to the posterior cartilaginous edge of this basal plate directly as the caudal fin-rays to the fan-shaped terminal bone of the vertebral column.

The pelvic fin is similarly supported by a triangular single bone, 31, which is attached to the lower end of the clavicle. It is usually called the *pubic* bone, though it is probably homologous, not with any part of the pelvic arch of Elasmobranchs, but with the basal cartilages of the pelvic fin in those forms.

A flat bone in the median plane extends forwards from the junction of the clavicles to the lower edge of the first basi-branchial. This bone, marked 28 in Fig. 3, has been called the urohyal by Huxley, basi-branchiostegal by Parker, but has really nothing to do either with the hyoid arch or the branchiostegal membrane; it is better to call it simply the *jugular* bone. Posteriorly it sends off a pointed ventral process, while the anterior three-fourths of it form a band of uniform width.

CHAPTER II.

THE FIBROUS MEMBRANES AND MUSCULATURE.

The Fibrous Membranes.

All the bones of the skeleton now described are bound together by strong fibrous membranes. In the median plane a tough membrane of this kind extends from bone to bone everywhere except in the median visceral cavity, so that the whole body of the fish, excluding the region of this cavity and the ventral region of the head, is divided into two lateral similar halves by a continuous partition consisting of a tough membrane supported by the bony framework. The structure of this partition in fact resembles that of one of the screens often used in our rooms to keep off draughts, the bones corresponding to the wooden framework, the membrane to the canvas stretched over it. But there is in the organic structure a more intimate connection between the fibrous membrane and the bony framework. Every bone is clothed externally by a tough fibrous membrane, the periosteum, and this is actually continuous with the membrane which connects the bones together. The whole structure is as it were a continuous deposit in which certain parts have been differentiated by the deposition of calcareous compounds and structural modification to form bone. Yet, tough and strong as the fibrous membrane is in its natural state, firm as it is found to be when the muscles are dissected away in the dead fish, if the fish is boiled for a short time it dissolves, and the bones all fall asunder. The reason of this is that the basis of the material of which the fibres consist is gelatine, and therefore though they retain their strength and structure during life, or in cold water, when subjected to the action of boiling water their structure is destroyed and they become simply a mass of soft liquid jelly.

The median fibrous membrane is continuous laterally with other membranes which are placed at right angles to it and connected with the vertebræ and interspinous bones. These lateral membranes run between the various muscles, which are attached to them, and externally become continuous with the derma, or deeper fibrous layer of the skin. The principal of the lateral membranes on each side runs longitudinally along the centre of the vertebræ from the skull to the tail, and extends outwards to the skin, thus dividing the muscles of each side of the body into a dorsal and a ventral

half. Shorter membranes transverse to this divide the muscles again into a series of oblique flakes which are seen separating from one another in a boiled fish brought to table.

In a symmetrical fish the median skeletal partition formed by the vertebræ and their spines and the interspinous bones terminates at the back of the skull, but in the sole it is extended still further anteriorly over the dorsal side of the skull to the extremity of the snout. The attachment of the membrane to the skull runs at first along the median dorsal line of the skull, that is, the morphological median line, but anteriorly it runs to the left of this line. It crosses the base of the left frontal bone and is continued along the edge of the large left ectethmoid and finally to the left edge of the mesethmoid. Thus, morphologically, the median skeletal partition is continued forwards on the left side of the facial region ventral to the left eye, though actually the anterior continuation is in the same plane as the main part of the partition. This anterior continuation is of course due to the anterior development of the dorsal fin which is supported by it.

Musculature.

A general view of the muscles of the right side of the sole is given on Plate XII. The white parts in that drawing represent the white tendinous membranes, excepting some of the bones of the head which are smoothly shaded, and the fin-rays: the shading of fine lines indicates the muscles, the lines being drawn in the direction of the muscle-fibres. The principal muscles of the body are the great lateral muscles, one dorsal and one ventral, separated from one another by the longitudinal fibrous membrane already described as projecting from the centra of the vertebræ outwards to the skin. Each lateral muscle consists of a longitudinal series of folded plates or segments, separated from one another by the transverse membranes previously mentioned. The fibres in the muscle-segments run in an antero-posterior direction parallel to one another, and are attached at each end to the transverse membranes, or to the bones and membrane in the median plane of the body. The transverse fibrous membranes have a curious folded and twisted arrangement. The outer edge of each, as can be seen from the illustration, has the form of the letter S. Starting from the longitudinal lateral membrane it curves first anteriorly, then posteriorly, and finally runs anteriorly again, thus forming two curves in opposite directions and a larger outer portion running obliquely forwards. The membrane itself is deeply hollowed forwards in the region of the first curve, backwards in that of the second, so that the inner edge of the membrane instead of being S-shaped is Z-shaped. This inner edge of the transverse membrane is attached to the median bones and membrane in the following way: it runs first along a vertebral spine for a short distance, then suddenly turns off at an angle and runs directly backwards till it reaches the next spine behind, along which it runs outwards (dorsally or ventrally) for some distance,

and then again leaves that spine and runs obliquely forwards. Thus each transverse membrane is attached by its inner edge to two adjacent vertebral spines at different parts of its length, and along the rest of its length is continuous with the median fibrous membrane which extends between the spines and the interspinous bones.

The anterior segments of the dorsal lateral muscle are much elongated and bent forwards, so that their separating membranes are attached to the dorsal surface of the skull, the anterior interspinous bones and the membrane connecting the latter.

The anterior segments of the ventral muscle covering the visceral region are straighter than the posterior, and the inner edges of the dividing membranes are not attached to any firm skeletal structure, but simply to the fibrous membrane which encloses the body-cavity, the peritoneal membrane. The ventral part of the ventral lateral muscle on each side is also separated from the median skeletal partition by the posterior prolongation of the body-cavity.

The posterior muscle-segments, in correspondence with the greater backward slope of the vertebral spines, are folded to a much greater extent than the anterior. The terminal segments form a system of muscles which are attached to the bases of the caudal fin-rays.

It follows from the description that in each lateral muscle there are as many muscle segments as there are vertebræ, and that each dividing membrane corresponds to a vertebra. Thus the muscle segments themselves correspond to the junctions between the vertebral centra, an arrangement which allows the vertebral column to be bent in all directions by the action of the lateral muscles. It is clear that, although it is difficult to understand in detail the effect of the complicated attachments above described in the contraction of the muscles, the general effect of the contraction of the lateral muscles of one side is to bend the body powerfully towards that side, and it is by this alternate bending of the body first to one side then to the other that the sole swims through the water when it rises from the bottom, or swims along the bottom. The lateral muscles form the bulk of the edible portion of the fish. The lateral muscles of the left or lower side do not differ in any important respect from those of the right.

The other muscles of the sole are the muscles of the fins and the muscles of the ventral region of the head, and the eye muscles.

The muscles of the longitudinal fins are well developed and important. The caudal fin-rays are, as has been mentioned, moved by muscles which represent the terminal muscle segments of the lateral muscles. The dorsal and anal fin-rays are moved by two distinct systems of muscles. One system serves to erect the rays and to depress them by causing them to slope backwards till they are almost parallel to the edge of the body. The other system moves the rays away from the median plane, either to the right side or to the left (upwards or downwards in the natural position of the sole). The muscles of the former system may be called the elevators and depressors of the fin-rays, those of the other the right and left abductors. The abductors of the fin-rays are superficial, lying immediately beneath the skin; there is a single muscle on each side

to each ray. These muscles take their origin from the fibrous tissue which covers the lateral muscles and which is continuous with the fibrous layer of the skin. Each muscle is inserted into the side of a fin-ray outside its articulation, but the end of the muscle also has connections by means of fibrous tissue with the ends of the interspinous bones.

The elevators and depressors lie beneath the abductors: there is one elevator and one depressor on each side of the body to each fin-ray. In the greater part of the fins the heads of the interspinous bones are between the bases of the fin-rays, and each elevator lies along the posterior half of the side of an interspinous bone, while each depressor lies along the anterior half. These muscles are considerably smaller than the abductors. They are inserted into the bases of the fin-rays in front and behind and take their origins from the surface of the interspinous bones and intermediate fibrous membrane. Their inner ends extend beneath the outer edges of the lateral muscles, which are free. The elevators and depressors of the fin-rays are shown in Plate XII. along the whole of the ventral side of the body and the anterior part of the dorsal side, while the abductors are shown along the posterior three-fourths of the dorsal side.

The muscles of the rays of the pectoral and pelvic fins are closely similar and require no special description.

The muscles of the ventral region of the head may be classified according to their functions into two divisions—the masticatory and the respiratory, the former moving the jaws, the latter the branchial arches.

The most powerful of the masticatory muscles is the common jaw muscle, which partly corresponds to the temporal and masseter muscles in man. Its origin occupies the outer surface of the "suspensorium," *i.e.*, the system of bones to which the mandible is articulated, and part of the surface of the skull. It consists of two portions, a superficial and a deeper, the former arises from the hyomandibular and the anterior edge of the preoperculum, and from the anterior part of the sphenotic, and from the basal portion of the right frontal; the deeper portion is smaller and arises from the metapterygoid, symplectic, and quadrate. Between the two portions runs a large nerve, the mandibular branch of the fifth cranial nerve. Both portions of the muscle on the right side of the head terminate in a tendinous structure which divides into two tendons, the upper is longer and thinner and is inserted into the middle of the posterior edge of the maxilla, the lower is shorter and broader and is inserted into the upper edge of the mandible, chiefly into the articular bone, a little in front of the articulation of the mandible with the quadrate. It is evident that the chief function of this muscle is to bring the jaws together, which it does principally by powerfully pulling the mandible upwards, while its upper tendon draws the upper jaw downwards and backwards. The muscle on the left side of the head is somewhat larger than on the right, and is inserted only into the mandible, the tendon passing to the maxilla being entirely absent.

The *levator suspensorii* is a muscle which arises from the sphenotic, especially from the lateral process of that bone, and is inserted into the head of the hyomandibular.

The depression of the lower jaw is effected by the paired geniohyoid muscles, each of which arises from the external surface of the hypohyal and ceratohyal, and is inserted into the inner surface of the symphysis of the lower jaw, that is to say, of the junction between the two mandibles of opposite sides.

From the lateral surface of the parasphenoid passes on each side a broad band of muscle outwards to the hyomandibular and pterygoid bones: these are the palatal muscles which constrict the cavity of the mouth in swallowing.

Behind the last there are other transverse muscles passing from the side of the skull to the inner surface of the hyomandibular and operculum.

A strong broad transverse muscle passes from the inner surface of one mandible anteriorly to the inner surface of the other; this is the *musculus transversus mandibulæ*. It lies immediately beneath the skin of the floor of the mouth, and assists considerably in the biting action of the mandible of the left side.

Most of these muscles, although chiefly concerned in seizing and swallowing food, are also used in inhaling water through the mouth for respiration. The following muscles connected with the branchial arches are almost entirely respiratory.

The most superficial of them is the *levator operculi*, which rises from the ridge and process of the pterotic and is inserted into the head and upper edge of the operculum: it raises the gill-cover.

The gill-arches are raised in inspiration by the *levatores arcuum branchialium*, which arise from the inner side of the articulation of the hyomandibular bone with the prootic and opisthotic, and are inserted into the outer surfaces of the bony branchial arches, into the epi-branchial bones.

Internal to the last are other muscles which pass from the inferior conical process of the basi-occipital to the pharyngobranchials of the 2nd, 3rd, and 4th branchial arches, that is, to the superior pharyngeal bones. The first pharyngobranchial bone, which is small and slender, lies along the side of the posterior end of the parasphenoid, to which it is connected only by connective tissue.

A powerful muscle posterior to the last passes from the lower surface of the anterior vertebræ forwards to the dorsal surface of the superior pharyngeal bones: this muscle retracts those bones, and is therefore inspiratory.

On each side two muscles arise from the anterior surface of the clavicle and pass upwards and forwards to the posterior surface of the inferior pharyngeal bone. As this latter bone is destitute of gills, and all the gill clefts lie in front of it, its retraction assists to open these clefts: these muscles are therefore inspiratory.

Expiration is effected by all the muscles which constrict the cavity of the mouth and throat, the jaws being shut first. In addition to some of those already mentioned the following, which bring the branchial arches into contact with one another, are expiratory.

Transverse muscles between the two inferior pharyngeal bones, and between the cerato-branchials of the 4th branchial arch.

Transverse muscles between the superior pharyngeal bones.

A strong flat muscle on each side which arises from the lower end of the clavicle and is inserted into the sides of the jugular bone.

Small muscles between the upper and lower extremities of the branchial arches.

The eye muscles in the flat fishes are of special interest on account of the peculiar distortion of the eyes which these fishes exhibit.

The eye muscles in the sole consist, as in symmetrical fishes, of four *recti* muscles and two oblique. The *recti* pass obliquely forwards from the back of the orbit to the outer surface of the eyeball, to which they are attached at equal distances; in a symmetrical fish, as in every other vertebrate, one is attached at the dorsal side, one at the ventral, one to the anterior, and one to the posterior: these are respectively named the superior and inferior, internal and external, *recti*. In the sole the superior *rectus* is uppermost in the natural position of the fish, having followed the torsion of the orbits without altering its position in relation to the interorbital processes of the frontal bones. Similarly the internal *rectus* of each eye is next to the interorbital septum. The superior and inferior *recti* of each eye are much thicker than the internal and external. All the *recti* of both eyes take their origin from the internal surface of the parasphenoid bone, within the cavity of the skull, but below the anterior part of the brain.

Of the two oblique muscles of each eye that which is nearest to the interorbital septum is the superior, the other the inferior. Their direction is transverse to that of the recti muscles. The superior passes outside the end of the internal rectus, and is inserted into the eyeball between the insertion of that muscle and that of the superior rectus. The inferior oblique passes outside the end of the inferior rectus, and is inserted between the insertion of that muscle and that of the external rectus. The origins of the oblique muscles in the sole and their direction are extremely peculiar and interesting. In a symmetrical fish the origins of these muscles are on the inner sides of the orbits, that is, on the side towards the median plane of the head. The median plane of the head in the sole is morphologically represented by the bony interorbital septum; the oblique muscles of the ventral eye in the sole do arise from the interorbital septum, those of the dorsal or right eye *do not*. The superior oblique of the ventral eye arises from the small left ectethmoid which is on the right edge of the interorbital septum; the inferior oblique arises from the external surface of the parasphenoid below the right ectethmoid. But both oblique muscles of the left or dorsal eye arise from the inner surface of the left ectethmoid, which is not part of the interorbital septum. The origin of the muscles is just outside the olfactory foramen. The surface from which the muscles spring looks to the right side of the sole, or, in the natural position of the sole, directly upwards. Thus the direction of the oblique muscles of the dorsal (left) eye of the sole is at right angles to the direction of those of the ventral (right). In fact, though the right ectethmoid bone has been shifted from its original position in the symmetrical fish to a very remarkable degree, the left ectethmoid is in the same position: it has been rotated but not shifted in position. The surface of the

left ectethmoid, to which the oblique eye muscles are attached, originally looked outwards to the left; now it looks upward, and it has become increased in size. Moreover, the left ectethmoid is still on the left side of the head, where it was originally before the distortion commenced. Another important fact is that the oblique muscles of the left eye are somewhat larger and stronger than those of the right.

These facts seem to me to have an important bearing on the question of the evolution of the sole and other flat fishes, of the process by which the peculiar asymmetry which characterises them was produced. All zoologists are evolutionists now, and it is generally admitted that the flat fishes are descended from remote ancestors which were symmetrical throughout their lives. This is sufficiently evident from the fact that all flat fishes when first hatched, and for some time afterwards, are at the present day perfectly symmetrical. But two entirely opposite views are at present held by different zoologists as to the process of evolution. One school of evolutionists goes beyond Darwin in one direction, the other in another. The former school believe that although the conditions of life and the habits of an individual animal do affect its structure, modify it in various ways, these modifications are never inherited and cannot therefore have anything to do with the process of evolution. All evolution according to this view is due to the natural selection of variations which are an advantage to the individuals in which they occur, and these variations are all due to causes existing before the development of the individual. Such variations are called congenital, and are inherited usually by the offspring of the individuals which possess them, and usually develop to a still greater degree in the offspring of two parents who both possessed them. These variations are entirely independent of the habits or conditions or the use and disuse of organs. Such evolutionists explain the distortion of the eyes in flat fishes in this way. A certain species of fish in remote ages found it necessary to lie on the bottom; among the individuals of this species some had eyes which were very slightly asymmetrical, the lower eye being slightly nearer the edge of the body than in the other individuals. Consequently these individuals being able to see more than the others lived longest, escaped their enemies, and left most offspring. As they bred together, and as variations again occurred, some of these offspring had the lower eye still nearer to the edge of the head, and these survived while the others perished, and so on, until in course of long ages the present flat-fishes were produced.

The other school of evolutionists believe that acquired characters are inherited to some degree. It is admitted that the use of an organ enlarges it and improves it, and they believe there is plenty of evidence that when the use of an organ in a particular manner is continued generation after generation the modification is partly inherited in each generation, and at last is wholly inherited. They hold therefore that the adaptations of organs to particular purposes, which are so conspicuous in animals and in plants, are due to the use of the organs for those purposes, and, though the modification

may be favoured and hastened by selection, it would take place without selection, while selection could not produce adaptations without the inheritance of acquired characters. They maintain, in fact, that there is no evidence of the occurrence of such variations as would give rise to adaptations except under the influence of stimuli and functional exercise.

Thus these evolutionists would explain the distortion of the eyes in flat fishes in this way. A species of fish took to crouching flat on the ground on one side of the body. But at first they did not lie perfectly flat, but slanting, lifting up their heads so as to use the lower eye, and using the muscles of this eye so as to turn the pupil into a horizontal direction, and look along the edge of the head. In consequence of this, the lower eye pressed on the interorbital septum, and caused it to be flattened. This pressure being continued for millions of generations the flattening and distortion of the interorbital septum came to be inherited until at last the two eyes were on one side of the head.

Now it is clear that no action of a given muscle of the eye could transport that muscle from one part of the head to another, and evolutionists who had not studied the anatomy of the head of flat fishes have made that objection to the above explanation. But no such transportation has occurred as was shown in the description given above. The attachment of the recti muscles of both eyes remains in the flat fish exactly where it is in the symmetrical fish. The cranial region and branchial region are unaltered. But the fishes which were the ancestors of the existing flat fishes, in order to twist the lower eye till its optical axis was almost parallel to the surface of the head, must have used the oblique muscles belonging to that eye. It is a physiological necessity that such a constant and extreme exertion of those muscles must in the individual have produced structural modifications, especially if it was commenced at an early age. The eye must have pressed on the interorbital septum in the sole on the left side, and this pressure would not have been counteracted by any pressure on the other side, for the right eye was required to look upwards and ventrally. Such pressure must have caused absorption and distortion of the interorbital septum, that is to say, the septum would by that alone have become thin and flat and bent to the right side. The increased exercise of the left oblique muscles must also have caused them to become larger and stronger, and also have resulted in the enlargement of the bone to which they were attached; for it is an established and certain fact that the exercise of a muscle causes it to increase in size and causes an increased development of bone at its attachment. But the direction of the strain of the muscles must have caused a torsion of the bone to which they were attached, so that the surface of attachment which originally looked outwards to the left came to look upwards. These are exactly the changes which we find to have taken place in the head of the sole. If the change had been due to the selection of variations which were independent of the effects of function, then we should expect that the left ectethmoid would have remained symmetrical with the right, for the left eye could

have been worked in its present position just as well if the oblique muscles had been attached to the side of the interorbital septum, as the right muscles are. But, on the theory for which I contend, there must have been some fixed point or fulcrum which remained fixed while the action of the muscles altered the position of neighbouring parts in relation to this fixed structure. The left ectetmoid of the sole fulfils the precise conditions required of such a fulcrum. A man cannot lift himself up in a basket, and the eye muscles could not by physiological effects have removed themselves bodily by their own action to a new position. But two muscles by straining on their own attachment, when unresisted by other muscles could twist neighbouring structures round that attachment, must in fact do so, the bone to which they were attached remaining in the same position and becoming enlarged. This is exactly what we find to have taken place in the sole. Thus the change which has taken place in evolution in the eyes and orbits of the sole is exactly of the same kind and in the same direction as, but much greater in degree than, the change which must have taken place in the individual fish which lay on its side and looked out with its lower eye beyond the edge of its head. Why, then, should we hesitate to conclude that the evolution has been due to the accumulation, by inheritance, of the modifications due to known physiological effects of functional activity? The only reason for hesitation is that some zoologists say that acquired characters are not inherited, an assertion which seems to me to be contrary to the evidence on the subject. However, this is not the place to enter upon a discussion of the question of the heredity of acquired characters. My purpose has been merely to describe the relations of the eye muscles to the orbits in the sole, relations which I believe are not accurately described in any existing anatomical treatise, and to point out that these relations are such as would necessarily have resulted if the distortion of the orbits and the migration of the left eye had been due in the course of evolution to the constant action of the oblique muscles of the left eye. It must be remembered that the other peculiarities in the structure of the sole, namely, the extension of the dorsal fin to the snout and the asymmetrical development of the jaws, are not in any sense consequences of the distortion of the orbits. In many flat fishes both eyes are on one side, as in the sole, while the jaws of the two sides are almost perfectly symmetrical, and the dorsal fin terminates behind the eyes. I believe that both these peculiarities in the sole are modifications due to physiological causes connected with the habit of lying on the left side; but it is certain, I think, that these physiological causes have nothing to do with the action of the oblique muscles of the left eye. In endeavouring to trace the evolution of the sole from a symmetrical ancestor each modification must be explained separately; the distortion of the eyes and orbits may be explained by the action of the oblique muscles of the eyes, but this cause does not in the least explain the absence of colour on the under side, nor the greater size of the jaws on the lower side, nor the anterior extension of the dorsal fin.

CHAPTER III.

THE VISCERA, AND VASCULAR SYSTEM.

The Viscera.

In the female the body cavity consists of three parts: a main central cavity, and two extensions or diverticula opening out of it. The central cavity is situated immediately behind the gill region and beneath the ten anterior vertebræ, and extends back to the anterior ventral interspinous bone. The two diverticula extend backwards from the main cavity, one on each side of the median skeletal partition of the body along the ventral edge. These lateral cavities extend from a little behind the anus to $\frac{1}{5}$th the length of the body from the tail, getting narrower dorso-ventrally towards the posterior end. The median anterior cavity contains the stomach and part of the intestine, the liver, and the spleen (*see* Plate VIII, 1). The right lateral cavity is the larger, and contains four parallel sections of the alimentary canal, also the right ovary. The left cavity contains only the left ovary and a part of the left kidney, which projects into it.

The liver is shaped like a flat cake with one surface smooth and the other made irregular by the entrance of blood vessels, &c. The greater part of this smooth surface is turned to the left, and occupies nearly the whole dorso-ventral extent of the main body cavity; it is the only thing seen in that body cavity on removing the left body wall. But the liver is doubled on itself anteriorly so that a smaller portion of the smooth surface lies beneath the body wall of the right side in the anterior part of the body cavity.

Projecting from beyond this surface towards the dorsal boundary of the body cavity on the right side is seen the gall bladder, which is spherical. The liver is attached to the anterior wall of the body cavity by a short ligament, situated in the median line towards the dorsal limit of the anterior wall, about 1 cm. long at its peritoneal attachment, and 3 mm. at its hepatic.

The œsophagus passes into the main body cavity at its dorso-anterior angle, dorsal to the liver, then with a very slight dilatation to form the stomach it passes backwards enveloped between the two parts of the liver, then following the boundary of the

main body cavity in the median plane the stomach curves downwards, ending at the pylorus at the ventro-posterior angle of the body cavity. Then commences the intestine, the first part of which may, as usual, be called the duodenum. At its commencement this is but little narrower than the stomach, but it rapidly narrows, and, passing forwards to the antero-ventral angle of the body cavity, bends at an acute angle and runs backwards and upwards along the border of the right fold of the liver, crossing the stomach on the right side to enter the right lateral body cavity along the dorsal part of which it runs to a little distance from its posterior end. The duodenum, like the stomach, is white, and has thick muscular walls, but towards the posterior end of the right lateral cavity it commences to get thinner walled and wider, and also darker from the contents seen through the walls. It now bends completely on itself, becoming considerably wider, and so passes into what may be called the ileum, which has extremely thin walls. This passes forwards along the ventral side of the right cavity in contact ventrally with the right ovary till it reaches to about the middle of the main body cavity where, lying on the right side of the duodenum, it again bends on itself and passes into the next length, which may be called the colon. At the bend, and about a centimetre on either side of it, the walls are again white, thick, and muscular, and the diameter of the tube is much reduced at this portion, which forms a kind of ileo-colonic valve, but internally there are no transverse folds of the wall, only longitudinal folds. After the bend the tube again dilates, this time suddenly, and the colon, with thin flaccid walls, passes back again into the right lateral cavity dorsal to the ileum, to a point about 2 cm. anterior to the end of the duodenum. At this point the colon, without any change of character, passes into the rectum, which passes forwards again on the dorsal side of and partially covering the colon, to the antero-ventral angle of the main body cavity, where it opens at the anus.

The spleen lies anterior to the stomach, between it and the liver, and a portion of it is sometimes visible on removing the right body wall, between the duodenum and the rectum. There is no pancreas, and no pyloric cæca. All the parts of the intestine and the liver and spleen are connected together by the branches of the splanchnic artery and portal vein: these are especially conspicuous between the duodenum and the liver, where they run from one to the other across the spleen.

The gall duct runs downwards from the gall bladder and opens into the duodenum a little behind the pylorus on the anterior side. The hepatic duct leaves the liver in the angle between the two folds and joins the gall duct about 1 cm. from the gall bladder.

Cutting through the œsophagus and the terminal part of the rectum we now remove the whole of the intestine, liver, and spleen, and examine the kidneys and ovaries.

The two ovaries extend, as has been said, along the ventral border of the right and left body cavities respectively. They are both about the same length, but the

right is thicker. The ovaries are not suspended by membranes (mesoaria) as in symmetrical fishes, but lie like kidneys beneath the peritoneum which passes over them. Morphologically the mesoarium may be considered to have fused with the surface of the median partition which separates the lateral body cavities from one another. Or, to regard the evolution in a different way, it may be that the ovaries have grown back post-anally beneath the peritoneum. Each ovary has a containing wall which is independent of the peritoneum, though attached to it: the latter can be separated from the former with facility. The ovarian artery and vein pass down together on each side from the posterior end of the main body cavity, and run along the dorsal side of each ovary. The walls of the two ovaries unite anteriorly on the ventral side of the main body cavity to form a single wide tube which opens to the exterior behind the anus and conducts the ova to the exterior. When the ovary is cut open the germinal surface covered with projecting ovigerous lamellæ having a general longitudinal direction, is seen to extend all round the internal surface except along the median ventral line, where the surface of the ovarian wall is quite smooth and destitute of ovigerous lamellæ: this probably represents the suture along which in development the edges of the ovarian lamina joined together to form a tube.

On the dorsal wall of the main body cavity the renal organs form a broad reddish band, placed in the centre and symmetrically, the two kidneys seem to be fused together in the middle line. No part of the renal mass is continued into the right lateral body cavity, but it is continued as a bulging thick mass into the dorsal part of the left lateral cavity, where it is in contact ventrally with the left ovary. From the ventral anterior corner of this mass there comes off a single short renal duct which opens out into a large urinary vesicle. This vesicle sends a prolongation backwards between the left ovary and the wall of the left lateral cavity, and it extends downwards behind the common oviduct, between this and the wall of the main body cavity, to open to the exterior on a small papilla on the right side. The opening of the oviduct, although in the same depression of the skin as the anus, is separated from the latter by a fold of membrane. Anteriorly the kidneys extend beyond the main body cavity between the œsophagus and the muscles dorsal to it, as far as the posterior surface of the skull.

Description of the Viscera of the male from a specimen 1 *foot long* (31 *cm.*).

Plate IX.

The intestines are arranged as in the female except that they do not reach quite so far back in the right lateral body cavity, that is, they are slightly shorter. In front of the bend which divides the colon from the ileum, is seen the urinary bladder, distended. No part of the testes is seen without disturbing the organs in the body

cavity. When the intestines are lifted up or removed, the right testis is seen, a triangular flat solid mass about 8 mm. broad at its posterior end, and 13 mm. long, lying at the anterior end of the right lateral body cavity, close to the front edge of the skeletal partition to which its inner surface is attached.

On the left side there is no left lateral body cavity, but the posterior portion of the fused renal organs extends backwards between the lateral muscle and the skeletal partition: this part of the kidney is as large in proportion as in the female, and has the same relations to the urinary bladder.

The left testis is only about half the size of the right. In this specimen it was 4 mm. broad above, and 10 mm. in length. The right testis is somewhat flat, and its greatest length is nearly antero-posterior in direction; the left has the form of a triangular pyramid with its point downwards, and its greatest length is dorso-ventral in direction. The left testis is situated in the main body cavity attached to the peritoneum over the surface of the kidney by a membrane, the mesorchium.

From the apex of each testis passes off the *vas deferens* or duct by which the milt or semen is conveyed to the exterior. Each *vas deferens* contains not a single cavity but several, and it is attached to the anterior surface of the urinary bladder. The *vasa deferentia* being translucent are not conspicuous; their external aperture is at the end of a small papilla on the right side, which is pierced also by the terminal part of the urinary duct. Thus in both sexes there is a papilla on the right side; in the female it is a urinary papilla, in the male it is urinogenital. In the figure the wooden rod is inserted through the anus into the end of the rectum, while the black bristle passes into the urinary bladder the walls of which are exceedingly transparent and indistinct, especially when the bladder is empty and collapsed.

Thus the male organs of reproduction in the sole are extraordinarily small in proportion to the size of the body. In other flat fishes, *e.g.*, the plaice, *Pl. platessa*, or merry-sole, *Pl. microcephalus*, they are smaller than the ovaries, it is true, but many times larger than those of the sole, and in the breeding season they become enlarged and soft, and of a milk-white colour. In this condition they at once attract notice when a male fish is cut open. In the sole, on the contrary, although the testes become slightly enlarged during the spawning period, they become neither white, nor soft, nor conspicuous. In fact they are not known to the fishermen, who are unable to recognise in the small yellow organs of the sole the male reproductive organs which they usually find in other fishes as large, white, soft, and conspicuous masses. The testes of the sole are, moreover, completely concealed beneath the intestine. Until recently even ichthyologists were for the most part unacquainted with the structure and relations of the male organs of the sole. In the Fifth Annual Report of the Fishery Board for Scotland, p. 233, it is stated that "the hatching of the sole, *e.g.*, presents this one great difficulty, that males are rarely ever captured, or, at least if captured, are seldom identified." As a matter of fact males

are captured in greater numbers than females, but fishermen are unable to distinguish the males from unripe or immature females.

One part of the viscera, which has the same relations in both sexes, still remains undescribed, namely, the anterior part of the intestine, and the gills which are connected with it. The anterior part of the intestine itself needs no very elaborate description: it consists simply of the mouth and throat, the walls of which differ only from the stomach in the fact that they are almost everywhere continuous with the surrounding muscles and other tissues, instead of being separated from them by part of the body cavity. Beneath the throat there is a part of the body cavity entirely separated from the rest, namely, the pericardium, which contains the heart, and which will be described below. The teeth previously mentioned as connected with or embedded in the superior and inferior pharyngeal bones of course project through the walls of the throat, and help to masticate or grasp the food. The series of basihyal and basibranchial bones, clothed with mucous membrane, form a pointed conical tongue in the floor of the mouth, which is used in swallowing.

At the sides of the throat is the important respiratory apparatus. Between the branchial arches are a number of clefts by which the cavity of the throat opens to the exterior. The bony arch is clothed with connective tissue, muscle, and mucous membrane, and this mucous membrane becomes continuous through the cleft with the outermost layer of the skin on the external surface of the body. The most anterior cleft is between the hyomandibular bone and the first branchial arch: the cleft extends upwards to the middle of the epibranchial bone, downwards to the end of the cerato-branchial. The 2nd, 3rd, and 4th clefts become gradually shorter, scarcely extending upwards beyond the cerato-branchials. The 5th cleft is very short, it is situated between the 4th cerato-branchial bone and the 5th cerato-branchial or lower pharyngeal bone. The latter is continuously connected by muscle and connective tissue with the pectoral arch; there is no cleft behind it. On the outer face of each arch there is a double series of long straight filaments, the branchial filaments. Each of these is supported by a rod of fibrous skeletal tissue which runs up its centre, and between this rod and the epithelium, or layer of delicate cells which covers the surface of the filament, there is a rich plexus of capillary blood vessels. The blood coursing through these gives out its carbonic acid to the sea water which passes through the gill clefts and absorbs oxygen from the sea water, which oxygen is necessary for the oxidization of the tissues that goes on throughout life.

In front of the first branchial cleft, running in an antero-posterior direction beneath the dorsal part of the hyomandibular bone, is a rudimentary branchia, composed not of long branchial filaments, but a few vascular folds of the mucous membrane: this is called the pseudo-branchia and is found in the majority of bony fishes. The pseudo-branchia represents part of the branchia of the hyoid arch. On the inner surface of the branchial arches there are small fleshy projections; in many fish these are long projecting rods called the gill rakers. In the sole they are rudimentary.

The branchiostegal rays support a membrane which is externally for the greater part of its length continuous with the opercular flap, but is free at its edge, and extends somewhat beyond the flap; it forms a concavity which directs the water pressed out in expiration upwards towards the base of the pectoral fin. The edge of the branchiostegal membrane is, in ordinary respiration, kept pressed against the posterior wall of the branchial cavity except opposite the base of the pectoral fin, where the membrane forms a small aperture by which the water that has passed over the gills escapes. The opercular flap supported by the opercular bones forms the external wall of the branchial chamber, in which the branchiæ are contained and concealed, but the opercular flap is morphologically nothing but a fold of skin projecting backwards from the hyoid arch and supported by dermal bones. The branchiostegal rays represent the branchial skeletal rods of the lower part of the hyoid arch: they have been much enlarged, and the filaments they supported have lost their branchial function, and coalesced to form the branchiostegal membrane.

Minute Structure of the Reproductive Organs and Development of the Reproductive Elements.

It has already been mentioned that the ovary consists of a hollow tube from the inner surface of the walls of which project a number of longitudinal lamellæ containing the ova. A section of a young ovary of the right side is represented in Pl. XIII, 1, as seen under a low magnifying power, namely Zeiss' objective A, ocular 2. The specimen from which this ovary was taken was $7\frac{1}{4}$ in. long, and was immature. But the structure of a mature ovary is similar in all respects except the size of the ova. The wall of the ovary consists of laminated fibrous tissue, and the ovigerous lamellæ are supported by projections of this tissue into the interior of the ovary. On the dorsal side of the transverse section are seen two blood vessels, the ovarian artery and vein. The ovigerous lamellæ are absent from a small portion of the ventral wall of the ovary, where the internal surface of the wall is smooth and barren. The surface of the ovigerous lamellæ is covered by a thin epithelium of cells too minute to be distinguished separately under a low power. Here and there in this epithelium young ova are seen developing. The epithelium is called the germinal epithelium, and from its cells all the ova are originally derived. The older ova are seen below the epithelium in the substance of the ovigerous lamellæ. The lamellæ contain in their centre a plate of somewhat dense fibrous tissue, from which a loose reticulum of fibrous strands and bands extends to the germinal epithelium. The older ova sink into this loose fibrous layer, and each ovum is surrounded and enveloped by strands of the fibrous tissue. The spaces in the fibrous reticulum are doubtless in life filled with lymph, while the tissue itself is richly supplied with capillary blood vessels. The

largest ova in the ovary at this stage are still very young, and each consists of a protoplasmic mass containing a nucleus. The nucleus is a spherical vesicle bounded by a membrane and containing protoplasmic strands and a number of nucleoli which are all situated at the periphery of the nucleus. In a stained preparation the nucleoli and the protoplasm of the ovum surrounding the nucleus are deeply stained, but the rest of the nucleus, consisting chiefly of liquid contents, is scarcely stained at all. Thus in each ovum the nucleus is seen as a clear central space containing several deeply stained globules arranged within its external border. There is little doubt that the fibrous connective tissue in the living state is more compact than I have represented it to be. The ova contract in the process of preparation and leave open spaces between them across which fibres are seen passing. But nevertheless it is certain that the fibrous tissue is reticular, and that it is traversed by spaces containing lymph.

When a portion of an ovigerous lamella from a young ovary is examined with a high power it presents the appearance shown in Pl. XIII, 2. The preparation from which this figure is taken was made from the ovary of a sole $10\frac{1}{2}$ inches long, killed in January. This also was an ovary which had never produced ripe ova, an immature ovary. It will be seen that the cells of the germinal epithelium are extremely minute and their outlines undefined. The ova are evidently produced by the enlargement of single cells of this epithelium, and as they increase in size they pass downwards into the fibrous "stroma." Even round the largest ova in an ovary at this stage no envelope can be detected except a fibrous membrane belonging to the "stroma" of the ovary. The protoplasm of the ovum, although it has grown in quantity, still exhibits no differentiation. The largest ovum represented in Fig. 2 is ·12 mm. in diameter.

But ova which are approaching maturity show a much more complicated structure. Fig. 3 is drawn from a section prepared from an ovary in the spawning condition; in fact the ovary was almost spent, but a few immature ova remained in it, and a section of one of these is represented in the figure. This ovum is seen to be enclosed by a thick envelope, exhibiting in section close set radiating lines. This envelope is not stained in the preparation. The radiating lines are really exceedingly fine tubules passing through the substance of the envelope and through these the protoplasm of the ovum communicates with the nutritive fluids outside. This envelope is the immature stage of the membrane surrounding the ripe ovum when it is shed, but at this stage it is much thicker in proportion to the size of the ovum than in the state of maturity. This envelope may be called the vitelline membrane; in the eggs of some fishes it is differentiated into two layers, but in the sole I can find no distinction except that the exterior surface of the membrane forms a kind of thin cuticle. The ovum within the membrane presents an appearance very different from that of the younger ovum previously described. Instead of a mass of granular protoplasm there are here a great number of spherical vesicles crowded together. These vesicles contain a number of

granules scattered through a transparent substance. They are the yolk vesicles. Attentive examination shows that the yolk vesicles are contained in the original protoplasm of the ovum, which everywhere extends among them, forming a network. In fact the yolk vesicles are developed by the protoplasm within itself. The protoplasm takes up the nutritive liquid materials derived from the blood and alters these by its living chemistry so as to form these yolk vesicles which grow as it were at all points throughout the substance of the protoplasm. In the mature ovum these yolk vesicles become homogeneous and transparent, and flow together, with the exception of a few of them, which remain separate but transparent near the outer surface of the ovum. In the ovum now under consideration the nucleus retains the structure described in the younger stage, and is still near the centre of the ovum. When the yolk vesicles fuse the nucleus passes to the exterior with the protoplasm, the whole of which forms a superficial layer enclosing the central semifluid yolk as in a bladder.

We have now to consider the ovarian structures surrounding the egg at the stage represented in Fig. 3. It is easy to recognise outside of all the thin membrane of fibrous tissue connected with and belonging to the stroma of the ovary. This may be called the follicular membrane, the ovarian capsule enclosing the ovum being usually known as the follicle. The follicular membrane exhibits nuclei along the course of the fibres composing it, and it contains a number of capillary blood vessels, communicating with larger vessels in the stroma (b.v. in Fig. 3). But within the follicular membrane is a regular epithelium which was not seen in the younger stage of the ovum. This is composed of a single layer of cells possessing large distinct nuclei. These cells in the preparation are separated from one another at their internal ends, but this is probably due to the contraction caused by reagents. Such a follicular epithelium is found round the ripening ova of all vertebrates. But it is still an open question whence it is derived. It has been maintained by many great authorities that the follicular cells are derived from the germinal epithelium; that when on ovum separates from the epithelium and sinks into the stroma it takes with it a few other cells of the epithelium, which multiply by division and form the follicular epithelium. This conclusion has been drawn mainly from the study of the ovary in embryos, not from that of developing ova in adult animals. As I have shown I have failed to trace any connection between the follicular epithelium and the germinal epithelium. The former seems to me to be entirely wanting for a considerable period after the young ovum has separated from the germinal epithelium. The cells of the follicular epithelium become visible about the same time as the commencement of the vitelline membrane. If these cells are not derived from the germinal epithelium they must be derived either from the egg itself or from the stroma of the ovary. There is no evidence of their derivation from the egg itself at least in bony fishes, and it is inconsistent with what we know of fibrous tissue to suppose that the nucleated fibres can produce cubical cells. The follicular cells cannot be developed independently from nutritive material derived from the blood, they must be descendants of previously existing cells, for we know of no

case in which nucleated cells arise, except as the progeny of other cells. There is thus only one source left to which we can attribute the origin of the follicular cells, namely, the colourless amœboid wandering lymph cells, which occur in the interstitial lymph spaces of all connective tissue. These cells are usually small, and it is possible that they might intrude themselves through the spaces between the fibres of the follicular membrane and so take up a position between that membrane and the surface of the vitelline membrane, and then growing in size form the follicular epithelium. The question of the origin of the follicular cells cannot however be considered as decided; Professor Emery in his monograph on Fierasfer, like myself, considers it improbable that they are derived from the germinal epithelium, but expresses no positive opinion as to their real origin.

As the egg in the ovary increases in size and approaches maturity its circumference reaches again the surface of the ovigerous lamella, and ultimately when it is quite ripe the germinal epithelium, the follicular membrane, and the follicular epithelium burst and the ripe egg enveloped only by the vitelline membrane escapes into the cavity of the ovary, whence it passes out through the external genital aperture to the exterior, where it is fertilised.

The structure of the testis of the sole is very different from that of the ovary, and closely resembles that of the testis in other bony fishes. Pl. XIII, 4, shows the structure of the testis of a young male sole 9 in. long, killed February 4th, 1889. The testis of a full-grown male sole is similar, but I have represented the transverse section of a small testis in order to include the whole of the section without making the figure inconveniently large. The substance of the organ consists principally of cylindrical tubes having walls of fibrous membrane and containing the spermatic cells. These tubes are closed at the end which is most remote from the testicular duct leading to the exterior, and these closed ends are all situated immediately beneath the surface of the organ. From the closed ends the tubes pass radially inwards towards the central region of the organ, except at the sides where their course is more longitudinal. The tubes are so numerous as to be in contact with one another along their sides. As in the case of the ovary the "stroma" of the organ consists of fibrous connective tissue which fills up the interstices between the testicular tubes and forms a thin layer round the organ externally. In the central region of the organ the testicular tubes communicate with a number of longitudinal tubes much smaller in number than the tubes themselves and of various sizes, some smaller, some larger, than the testicular tubes. These longitudinal tubes convey the spermatozoa towards the efferent ducts, and do not themselves produce spermatic cells: they are scattered with no regular arrangement through the dense fibrous stroma. Inferiorly the fibrous stroma of the testis is looser in texture and becomes continuous with the fibrous connective tissue of the wall of the body cavity to which the testis is attached. Thus, to use the terms frequently employed in human anatomy, the testis of the sole consists of a cortical portion and a central medulla, the cortical portion consisting of tubes placed

perpendicular to the surface, their outer ends being closed, and the medulla of longitudinal tubes separated from one another by fibrous connective tissue. This medullary portion is prolonged beyond the organ itself in the form of a band which passes down the surface of the urinary bladder to the genital opening. Sections of this band show that the longitudinal efferent tubes do not unite into a single duct or *vas deferens*, but are only slightly reduced in number by coalescence, so that a large number of tubes remain separate even to the external opening. Fig. 6 exhibits a section of the cord or band connecting the testis with the exterior and containing the separate efferent tubes. This section is more highly magnified than that shown in Fig. 4, and is taken from the testis of a full-grown male preserved while in full generative activity, in March, 1889. The spermatozoa are seen within the efferent tubes, completely filling the cavity of some of them, and appearing under a low magnifying power as deeply stained granules: these granules are the heads of the spermatozoa, the tails or vibratile appendages not being visible.

If the cortical tubes in the section shown in Fig. 4 are examined under a more powerful objective, each of them presents the structure shown in Fig. 5. At the closed end of the tube are a number of large polygonal cells forming an epithelium. Each of these cells has a large nucleus with many nucleoli; lower down the tube is filled with smaller and smaller cells produced by the division of the large cells. The large cells are evidently constantly being multiplied by division, and after reaching a certain size each is pushed down into the cavity of the tube where it divides and subdivides, forming a cluster of smaller cells. In some parts of the tube such clusters of small cells produced from a single original cell can be distinguished, but they easily break up and the cells of various clusters are confused together. In some of the young clusters near the closed end of the tube all the nuclei are seen in a state of division showing that each cell is dividing into two.

The large cells at the closed end of the tube correspond to the germinal epithelium of the ovary; they do not extend down the sides of the tube, but are confined to its end: they are the male germinal cells and from them all the spermatozoa are produced.

As the cells pass down the testicular tube they get smaller and smaller, and in the lower ends and in sections of the deeper portions cut transversely they are seen to have reached their limit of subdivision, for amongst them are seen deeply stained minute spherical bodies which are the heads of spermatozoa. The minute cells produced by continued subdivision are converted into spermatozoa and are called the spermatoblasts. The details of the development of a spermatozoon from one of these spermatoblasts can only be followed out by teasing up a portion of the testis on a glass slide and examining it microscopically with the aid of reagents. The process cannot be followed satisfactorily in sections because in these the elements are cut up into pieces. I have not followed the process of development in the sole; I will therefore merely explain here that the protoplasm of the spermatoblast elongates

into a slender filament, while the nucleus alters in properties, imbibing stains such as carmine more intensely, and forms what is called the head of the spermatozoon. During the spawning period all the testicular cells, except the large cells of the male germinal epithelium at the closed ends of the testicular tubes, are converted into spermatozoa, which are conveyed to the exterior suspended in a liquid similar to lymph. This liquid is produced within the testis, being probably exuded from the blood vessels and lymph of the testicular stroma into the testicular tubes. The liquid containing the spermatozoa is usually called the milt. When the spermatozoa reach the sea water they swim about actively, and when one meets a ripe ovum it enters its substance and fertilises it.

The Vascular System.

The blood vessels ramify through all the tissues, including the skin and nervous system, which have not yet been particularly described. But as the heart, which is the central organ of the vascular system, is closely related to the body cavity and to the branchiæ, the system may be conveniently described here.

The heart, as was before mentioned, is enclosed in a special chamber of its own, which is really a part of the body cavity, though it is entirely shut off from the visceral cavity in which the organs of digestion, &c., are contained. This cavity containing the heart, the pericardium, is situated between the posterior and internal walls of the two branchial chambers; the cavity is wedge-shaped, the edge of the wedge being anterior, the base posterior. Posteriorly the pericardium is separated from the visceral cavity by a thin membrane which lies in front of the liver and below the gullet or œsphagus. Outside the pericardium on either side is the bone called the clavicle. The heart itself is conical in shape, the point being ventral and directed downwards and slightly forwards, the broad base being dorsal. It is hollow and divided into two portions connected by a valve. The dorsal portion has very thin walls, and is called the auricle; the ventral portion has thick muscular walls, and is called the ventricle. Into the dorsal end of the auricle open three large veins by which the blood which has passed through the various parts of the body is conducted into the cavity of the auricle. These veins are the *ductus Cuvieri* which pass one on either side of the œsophagus from the kidneys, and the hepatic vein which passes forwards from the liver below the œsophagus. The *ductus Cuvieri* of each side is formed by the union of two veins, one running forwards in the substance of the kidney and conveying the blood from the trunk, the other running backwards from the head and conveying the blood from the brain, skull, &c.; these are called the anterior and posterior cardinal veins.

The ventricle sends off a single main blood vessel, the ventral aorta. At the opening of this vessel from the ventricle, there are three internal folds or valves which prevent

the blood returning to the ventricle. This vessel passes forwards along the dorsal edge of the jugular bone, and beneath the basi-branchials it divides, giving off on each side an artery to each of the first four branchial arches; from the artery of the first arch a branch passes to the pseudobranchia. The fifth arch, bearing no branchial filament, does not receive a special branchial artery. The branchial arteries run along the branchial arches giving off smaller vessels which break up into the capillaries of the branchial filaments. These capillaries unite again into the efferent branchial vessels which run in the branchial arches towards the dorsal side of the pharynx or throat, where they unite together into a single median dorsal aorta. From the efferent branchial vessels are given off arteries which supply the brain, skull, and other parts of the head. From the dorsal aorta is given off at the anterior end of the body cavity the cœliac artery which supplies the intestine spleen, and liver with arterial blood. The dorsal aorta runs backwards in the canal formed by the series of divergent bases of the ventral spines of the vertebræ, and is therefore in its anterior part dorsal to the kidneys. It gives off special arteries which descend to supply the generative organs. It also throughout its course gives off a pair of arteries to each segment of the lateral muscles, from which branches supply the skin, bones, and all parts of the body.

The return of the exhausted venous blood from the tissues to the heart takes place by a somewhat curious route. The veins of the head unite into the two anterior cardinals, already mentioned, one on each side. But nearly all the veins of the trunk fall ultimately into the caudal vein which runs forwards in the same bone-protected canal as the aorta, as far as the interval between the ventral spines of the ninth and tenth vertebræ, where it bends suddenly towards the ventral edge of the body and enters the dorsal side of the renal mass. The veins of the trunk in front of the caudal vein fall into the kidney by separate collecting veins. A number of the veins of the ventral side of the trunk, behind the kidney, unite into a longitudinal vein, which runs forwards along the left side of the median skeletal partition and enters the posterior apex of the part of the kidney which extends backwards on the left side behind the main body cavity. Thus nearly all the venous blood in the trunk is conveyed into the renal mass, where the urinary excretion is extracted from it, and whence it is passed on by the posterior cardinal veins to the heart. The veins of the spleen and intestines on the other hand unite into a single vein which enters the liver where it breaks up into capillaries, and these unite again to form the hepatic vein which opens into the auricle.

CHAPTER IV.

THE NERVOUS SYSTEM

The Brain.—The brain of the sole has no very special features which distinguish it among those of other bony fishes. The position of the brain is almost entirely unaffected by the change which has taken place in the normal position of the fish; the posterior part of the skull, as was previously pointed out, has neither twisted nor become asymmetrical, and the corresponding part of the brain also retains its original position and symmetry. But it seems still more remarkable that the anterior part of the brain has not to any great degree followed the anterior part of the skull in the rotation which the latter has performed. When the brain is exposed from the upper (right) side of the fish, the right side of the organ is seen, the extreme anterior end being alone very slightly turned round towards this side. This absence of change in the position of the brain is not so paradoxical when we compare carefully the relation of the organ to the skull. The anterior end of the brain lies beneath the posterior portions of the frontal bones, and these retain their original position.

It might have been expected that the change in the position of the anterior cranial nerves would have caused a greater twisting of the brain; but we find that the trunks of the nerves have moved while their roots have been very slightly affected.

Viewed from the dorsal side the brain exhibits the same series of ganglionic masses which are seen in other bony fishes. At the posterior end is the single median globular cerebellum which projects backwards above the anterior thickened continuation of the spinal cord, called the medulla oblongata. In front of the cerebellum is the pair of masses whence the optic nerves arise, the optic lobes, each of which is almost as large as the cerebellum; in front of these again is the pair of cerebral hemispheres which are slightly smaller than the optic lobes, and immediately in front of the cerebral hemispheres are the olfactory lobes. In some bony fishes the olfactory lobes are removed to some distance from the brain and placed in proximity to the olfactory capsules, being connected with the brain by long nervous peduncles or *crura*; *e.g.*, in the cod and carp. But in the sole as in other flat-fishes, and in the perch, mackerel, pike, gurnard, and others, the olfactory lobes form part of the brain and are at a distance from the olfactory capsules; with which they are connected by the olfactory nerves.

The under surface of the brain exhibits beneath the cerebellum the continuation forwards of the medulla oblongata which forms as it were the stalk supporting the dorsal lobes. Beneath the front part of the optic lobes, however, an inferior outgrowth is seen; this consists of a pair of lobes called the lobi inferiores between which is a vascular organ called the pituitary body, or *hypophysis cerebri*, supported on a hollow conical outgrowth called the *infundibulum*.

The brain contains a central cavity which is the continuation of the central canal of the spinal cord. This cavity terminates in the middle line between the cerebral hemispheres, but laterally it sends off two diverging prolongations into the interior of these hemispheres. The medulla oblongata and its continuation, the crura cerebri, are situated below the central cavity, while the cerebellum, the optic lobes, and the upper part of the cerebral lobes are enlargements of the roof of the cavity. The infundibulum and pituitary body form a downward diverticulum of the cavity beneath the point where it bifurcates into the cavities of the cerebral lobes; and a corresponding diverticulum towards the dorsal side exists between the anterior part of the optic lobes, and is called the pineal gland. The pineal gland, like the pituitary body, is a vascular structure in fishes. In some reptiles it has been found to have a structure resembling that of the vertebrate eye.

The olfactory lobes are continuous with the inferior portion of the cerebral hemispheres. In the sole the left olfactory lobe is somewhat larger than the right, a difference which is related to the great development of the left olfactory capsule. But there is no inequality in the size of the optic lobes or optic nerves, such as that which according to Owen occurs in the halibut and some other *Pleuronectidæ*. In Owen's figure of the halibut the right optic lobe and left optic nerve are the larger; the eyes of this species, as of the sole, are on the right side, so that the larger structures are those belonging to the eye which has migrated.

It would naturally be inferred that the left eye was larger than the right in the halibut, but I have not been able to find any allusion to an inequality in the size of the eyes themselves.

As in all bony fishes the brain of the sole is much smaller than the cavity in which it lies. The widest part of the cavity within the skull is the posterior part: here the brain passes forwards from the *foramen magnum* as an axis in the centre of the cavity, the surrounding space being occupied by the auditory organs. The *sacculi* meeting in the middle line below, occupy the space below the brain, while the semicircular canals intervene between the latter and the skull-walls dorsally and laterally. A transverse ridge on the inner surface of the skull-wall, forming part of the sphenotic and prootic bones, limits anteriorly the cavity occupied by the *sacculi*. In front of this ridge is another ventral depression occupied by the optic thalami and pituitary body, while above the optic lobes and cerebral hemispheres there is a considerable space occupied only by spongy connective tissue containing fluid—the arachnoid membrane. The internal hollow of the parasphenoid bone in front of the pituitary

body is occupied by the insertion of the muscles of the two eyes, these muscles being separated from the interior cavity of the skull by a tough membrane, continuous with the dura mater posteriorly, and anteriorly with the membrane which completes the septum between the orbits. This membrane is pierced for the exit of the optic, olfactory, and other nerves, and on it rest the olfactory lobes.

The Cranial Nerves.

The olfactory nerves pass from the olfactory lobes to the olfactory capsules, terminating in the olfactory epithelium of these organs. Owing to the rotation of the left eye and orbit the position of these nerves in the sole is peculiar. Each olfactory nerve in all fishes passes over the dorsal side of the recti muscles of the eye. The relations of the nerves to surrounding structures are not altered in the sole, but the rotation of the eyes has brought the olfactory nerves into asymmetrical positions. Thus both of these nerves are apparently on the upper (right) side of the head, though morphologically they are on opposite sides. Both of them, like other structures connected with the orbits, are on the coloured side of the head, to the right of the anterior part of the dorsal fin. The left nerve passes above the recti muscles of the left eye close to the interorbital septum, and in front of these muscles bends downwards and passes through the large foramen in the left ectethmoid bone (Pl. XI, 6, I) to reach the left olfactory capsule on the lower side of the head.

The right nerve has a perfectly straight course along the ventral (right) side of the interorbital septum, dorsal to the *recti* muscles of the ventral (right) eye. It passes through the foramen in the right ectethmoid without any bending, and then bends slightly downwards to the olfactory capsule of the upper (right) side.

Each of these nerves, though spoken of in the singular, consists of a bundle of separate nerves, which are separate throughout their course, and not united into a single cord.

The optic nerves, as usual in bony fishes, cross one another at their origin without mingling. The dorsal (left) nerve is very slightly longer than the ventral (right). The left arises from the lower side of the right optic lobe in front of the *lobus inferior* or optic thalamus, the right from a corresponding position on the left side. The optic nerve passes between the internal and superior *rectus* close to their origin into the space enclosed by the *recti* muscles, and so reaches the eye-ball.

The third, fourth, and sixth pairs of cranial nerves are motor nerves all distributed to the muscles of the eyes. The third pair are called the *motores oculorum* and split up into branches which enter the superior, inferior, and internal *recti*, and the inferior oblique muscles. The fourth pair of nerves are called *trochleares* and supply the superior oblique muscles exclusively. The sixth pair are called *abducentes*, and enter only the external *recti* muscles. These nerves arise from the sides of the lower part of

the brain behind the origins of the optic nerves, and pass from the skull by apertures in the membrane which closes its anterior opening.

The fifth nerve or trigeminal arises by several roots from the side of the medulla oblongata below the cerebellum: in its origin it is closely connected with the seventh or facial nerve. In fact the two nerves arise from a number of roots common to both, of which the dorsal are sensory, the ventral motor; the fifth nerve is chiefly composed of fibres from the sensory roots, with the addition of some from the motor, while the facial consists chiefly of fibres from the motor roots, with the addition of some from the sensory.

The fifth nerve consists of a large number of branches. It does not leave the skull by a single trunk, but divides on the inner wall of the skull into several, the largest and most important of which leaves the skull after a very short course by the large trigeminal foramen in the lower part of the sphenotic bone. The other two branches run for some distance on the inner wall of the skull before emerging: one of them runs directly forwards and emerges through the anterior membrane which separates the skull from the orbits; this forms the orbito-nasal nerve; the other curves upwards and forwards and emerges by a small foramen in the frontal bone. As the corresponding nerves differ on the two sides it will be necessary to describe them separately.

The course of both orbito-nasal nerves, like that of the two olfactory, is to be followed by dissection of the upper side of the head; for each orbito-nasal nerve lies in close relation to the olfactory, lying in the ordinary fish dorsal to the olfactory and between the eye muscles and the interorbital septum. Accordingly in the sole the orbito-nasal nerves are found on the upper side of the head, one on either side of the interorbital septum. But the dorsal (left) is much larger, and longer than the ventral (right). The left nerve passes over the surface of the mesethmoid bone at the bottom of the rounded notch between the left ectethmoid and the mesethmoid, and then enters the gelatinous tissue of the end of the snout, sends branches to the skin of the upper side at this part of the snout, but is chiefly distributed to the tactile filaments of the skin on the lower side between the olfactory capsule and the edge of the snout. The right nerve just behind the right ectethmoid passes into a canal between the right frontal bone and the right ectethmoid, and thence emerges again on the right upper surface of the mesethmoid, enters the gelatinous tissue of the snout, and supplies the small area of skin on the upper side between the mouth and the apex of the snout.

The right dorsal branch of the fifth, after its upward course on the internal surface of the skull, emerges by a small foramen in the flat proximal portion of the right frontal bone, and thence passes forwards, at some depth from the surface, between the cephalic portion of the lateral muscle and the membrane which forms the dorsal boundary of the dorsal (left) orbit. It supplies the skin of the extreme anterior end of the dorsal fin on the upper side. It seems at first sight that this nerve has changed its morphological relations; for since it belongs to the right side of the head we might expect to find its anterior part on the ventral or right side of the interorbital septum,

with the right orbito-nasal; whereas it actually runs on what is morphologically the ventral side of the left eye, crossing in its course the left olfactory and orbito-nasal nerves. But the explanation of this apparent anomaly is not difficult. The dorsal branch of the fifth is a sensory nerve and was connected in the original symmetrical fish with the skin of the extremity of the dorsal fin which was originally posterior to the eyes. The fin remained behind the eyes during the rotation of the latter, and after the left eye had travelled round to the right side, the dorsal fin with the neighbouring muscles began to extend forwards. But instead of extending forwards along the now distorted median dorsal line, the fin grew forward along the edge of the left ectethmoid bone, which supports the left eye in its new position, and which is morphologically ventral to the left eye. The nerve connected with the fin necessarily accompanied the latter in its growth, and thus this nerve comes to be actually dorsal and morphologically ventral to the left eye. The origin of the nerve remains in its original position posterior to the eyes on the right side of the skull.

The corresponding nerve of the left side makes its exit from the skull from a corresponding foramen in the flat proximal portion of the left frontal bone, on the lower (left) side of the dorsal fin; it passes forwards on the left side of the fin to its apex.

On the right side the trunk of the fifth nerve, which emerges from the skull through the sphenotic foramen, divides immediately after its exit into two large branches, the maxillary and mandibular nerves. The maxillary branch supplies with sensory fibres the skin of the upper jaw and also sends motor fibres to the palatal muscle. The mandibular branch supplies with sensory fibres the skin of the lower jaw; the largest division of it enters a canal in the mandibular bone, whence it supplies the mucous membrane of the floor of the mouth. The main trunk of these two branches, the maxillary and mandibular, while still within the skull, gives off a small nerve which leaves the skull by the great anterior opening, and passes forwards below the *recti* muscles of the eye; it supplies the anterior part of the palate and is called the palato-nasal.

On the left side these branches of the fifth are much enlarged, their sensory fibres being multiplied in proportion to the great development of tactile filaments and epidermic sense-organs on this side. The palato-nasal branch reaches this side of the head partly through the gap between the ectethmoid and parasphenoid, partly through a foramen in the sphenotic in front of the large sphenotic foramen. The latter foramen is much larger than that on the right side, and the common trunk of the maxillary and mandibular nerves which passes through it is proportionally large. These branches of the fifth on the left side are represented in Pl. XV, 2, where the maxillary is indicated by V 2, the palato-nasal by V 2a, and the mandibular by V 3. The dorsal branch of the fifth, which accompanies the dorsal fin, is seen passing forwards just above the palato-nasal.

The seventh cranial nerve is called the facial; its distribution is the same on both sides, as it belongs to a region of which the symmetry has not been disturbed. The

principal trunk of the facial leaves the skull by a circular foramen in the prootic bone, and then passes through a foramen in the head of the hyomandibular. But after this it is still covered by the preoperculum, which must be removed before the distribution of the nerve can be observed: the facial runs for some distance between the hyomandibular and the preoperculum. Soon after its exit from the hyomandibular foramen the nerve trunk divides into two branches, the posterior of which is the *ramus opercularis*, the anterior the *ramus hyoideo-mandibularis*. The *ramus opercularis* (VII 2a, Pl. XV, 2) divides into branches which are distributed to the skin of the operculum. The *ramus hyoideo-mandibularis* divides into two branches, one of which, the *ramus mandibularis*, VII 1, runs along the anterior part of the surface of the quadrate. It gives off branches to the jaw-muscle, and into the substance of the quadrate, and passes through a foramen in the head of the quadrate to the inner side of the mandibular bone, where it supplies the transverse mandibular muscle, the genio-hyoid muscle, and the mucous membrane of the floor of the mouth. The other branch, the ramus hyoideus, VII 2, bends inwards to reach the inner side of the stylohyal bone, and is distributed to the inner surface of the hyoid arch.

The eighth cranial nerve is the auditory, which never leaves the interior of the skull, but is exclusively distributed to the auditory organ: it is the auditory nerve.

The ninth cranial nerve is called the glosso-pharyngeal, a name taken from human anatomy, but not at all appropriate to the anatomy of fishes. This nerve, like the seventh, is distributed in the same way on each side. It makes its exit from the skull by a special small foramen in the opisthotic bone, arising from the *medulla oblongata* by an independent root. On the trunk of the nerve, a little beyond its exit from the skull, there is a ganglion of considerable size, below which the nerve bifurcates into two branches. The anterior branch goes to the posterior surface of the operculum and hyoid arch, the posterior to the anterior surface of the first branchial arch.

The tenth cranial nerve, called *nervus vagus*, is more widely distributed than any of the others, and represents a series of nerves united into a common trunk at their origin. The single trunk passes out of the skull through a circular foramen in the exoccipital bone, and then divides into several branches. The first branch, the most anterior, bifurcates into two, and has a large ganglion at the point of bifurcation; it forks over the second branchial cleft, the front branch going to the posterior face of the first branchial arch, the posterior branch to the anterior face of the second branchial arch. Similarly the second branch of the vagus bifurcates over the third branchial cleft, and has a ganglion at its point of bifurcation. The third branch has no ganglion, but bifurcates in the same way over the fourth branchial cleft. The fourth branch bifurcates over the fifth branchial cleft, its anterior branch going to the posterior face of the fourth branchial arch, its posterior branch to the posterior wall of the branchial chamber and the fifth branchial arch. A nerve from this branch goes to the heart. The fifth branch of the vagus runs down the œsophagus to the stomach. The sixth branch is the lateral nerve or nerve of the lateral line: it runs close above

the vertebral centra on the ventral side of the band of connective tissue which separates the dorsal and ventral lateral muscles. From this position it sends off nerves which supply the sense-organs of the dermal canal of the lateral line. At its origin this nerve gives off on each side a branch which curves upwards and forwards and runs immediately beneath the skin along the course of the supra-temporal dermal canal on the right side, the series of supra-temporal superficial sense-organs on the left side. On the left side there is another nerve given off from the lateral nerve at its origin : this nerve runs immediately beneath the skin straight forwards across the side of the lateral ridge of the skull : it supplies the superficial sense organs of the epidermis which lie along this direction. The two nerves last mentioned are shown in Pl. XV, 2, indicated as X 6a and X 6b.

Pl. XV, 2, exhibits the cutaneous branches of the cranial nerves on the left side, and is intended to show the great development of these branches which has taken place in connection with the numerous tactile filaments and epidermic sense-organs which have been developed on the skin of the left side of the head.

CHAPTER V.

THE SKIN.

The skin everywhere consists of two layers very different from one another in structure. The lower layer, which is much the thicker, consists of fibrous connective tissue, forming a dense tough membrane. This layer is about $\frac{1}{25}$th of an inch thick (1 mm.). It is clothed externally by a thin layer of cells, the longer axis of which is perpendicular to the surface of the body: this is the epidermis. The lower layer or derma contains the scales, the ends of which project backwards through the epidermis, and the pigment cells or chromatophores. On the lower side of the head anteriorly the skin forms a number of flexible papillæ, or filaments, which are delicate tactile organs. The skin is continued over the eyes, but the part which covers the eye is thin and perfectly transparent. Scales are present in the skin everywhere, except over the eyes and in the region of the tactile filaments. The scales can be detached from the skin without difficulty, and when separated and examined with a low power of the microscope present the appearance shown in Fig. 1, Pl. XIV. The largest scales are in the central region of the surface of either side. The scales consist of plates of fibrous tissue hardened by the deposition of lime-salts. Each has the form of a rectangle at the posterior end of which is a portion bounded internally by two straight lines meeting at an obtuse angle, outwardly by a semicircular curve, and covered with sixteen rows of spines. In each row the outermost spine is the largest, the others becoming gradually shorter: there are five spines in each row, and the rows radiate from the angle at which the internal bounding lines of the spinous area meet. This spinous area is the only portion of the scale which is exposed at the surface of the skin, the remainder being imbedded in a socket and overlapped by adjacent scales; they are placed with their longer axes directed backwards, and each overlaps the one behind it. They are arranged quincuncially, that is, each scale in any transverse row lies over the line where the edges of two adjacent scales of the row behind meet one another. In consequence of this quincuncial arrangement the transverse rows, which are perpendicular to the longitudinal axis of the fish, are not easily recognised; but two series of oblique rows are visible, one series running downwards from right to left, the other downwards from left to right. In the same way in the pattern of a wall paper when there is a figure repeated at equal distances in lines crossing one another at right

angles, but arranged quincuncially, the rectangular lines cannot easily be followed, but two oblique or diagonal series become conspicuous. It is the oblique rows of scales, either those from right to left or from left to right, which are counted in describing the specific characters of a fish.

The imbedded portion of a scale exhibits a number of parallel curved lines, the edges of the laminæ of which it is composed. The directions of these lines divide this portion of the scale into three areas: a triangular area bounded by the anterior edge of the scale and two lines which meet at an acute angle near the anterior apex of the spinous portion, and two similar areas on either side of this. The anterior portion is divided up by a number of radiating straight lines, into radiating strips, each of which is occupied by a series of short curved parallel lines. The two other areas are occupied by lines parallel to the dorsal and ventral edges of the scale.

The scales of *Solea lascaris*, *variegata*, and *lutea* resemble those of *S. vulgaris* in structure. The scale of *lascaris*, Fig. 4, Pl. XIV, is the largest: it has the same general shape as that of *vulgaris*, but the spines are more pointed, and there are seventeen rows of them, and six spines in each of the central rows. The scale of *variegata*, Fig. 3, is shorter in proportion to its breadth than that of *lascaris*, it has 26 rows of spines, with eight spines in each central row: the spines, except the most external, are short and blunt. The scale of *lutea*, Fig. 5, is the smallest of the four: in shape it resembles that of *vulgaris*; it has 21 rows of spines, four spines in each of the central rows; the spines are rather short and pointed.

The "lateral line" which runs down the centre of each side of the sole is formed by a series of scales which are very different from the ordinary scales of the body. They have no spines, and no portion of them projects beyond the surface of the skin. One of these scales from *Solea vulgaris* is represented in Fig. 2, Pl. XIV. Anteriorly its structure resembles one of the ordinary scales, but posteriorly it is narrowed to a blunt apex and the spinous portion is wanting. On its external surface, for a little more than half its length posteriorly, there runs a kind of tunnel with rounded roof which, with the scale below, forms a tube open at both ends: this tube or tunnel is broader in front than behind. In the floor of the tunnel, not far from the posterior end of the scale, is a large oval aperture. These scales of the lateral line overlap one another in such a way that the aperture in the floor of the tunnel of one is just in front of the anterior aperture of the tunnel of the scale behind it.

Dermal Canals and Sense-organs.

This system consists of a number of connected tubular channels running in the derma or in bones originally derived from the derma. The longest and most easily observed of these tubes runs beneath the lateral line. It is lined by a cellular layer somewhat similar to the superficial epidermis, and it runs through the series of bony tubes just described as belonging to the scales of the lateral line. Tracing the tube

from before backwards we find that the tube enters the anterior end of the tunnel on each scale and passes through the aperture in the floor of the tunnel to enter the tunnel of the next scale, and so on. But before passing through the aperture in the floor of the tunnel the tube gives off a branch which continues to run through the tunnel to its posterior aperture, and passes beyond the scale to open by a pore on the surface of the skin. Thus corresponding to each scale of the lateral line there is a pore in the skin which leads into the dermal tube of the lateral line. The course of the tube and its relation to the scales are exhibited in Fig. 6, Pl. XIV, which represents an ideal longitudinal section of the skin along the lateral line: sc. indicates the scales in section, d.t., the tube, p, the external pores. The left end of the section is the anterior. On the inner wall of this lateral dermal tube are a number of sense-organs supplied with branches of the *nervus lateralis*, which in the sole as in the majority of fishes is a branch of the vagus. If we follow the lateral dermal tube forwards we find that at the side of the back part of the skull, over the parietal crest, it becomes separate from the skin and enters the hinder branch of a triradiate bony tube: one branch of this bone passes straight forwards for a short distance and then terminates, and the lateral tube then enters a tube in the pterotic bone. This tube excavated beneath the surface of the bones of the skull is continued forwards, sometimes opening into a groove on the lateral ridge of the skull: it passes just above the posterior corner of the sphenotic bone, and then enters the outer edge of the posterior half of the frontal; then it is continued as an enclosed tube through the interorbital process of the frontal, and emerging from this enters a separate tubular bone similar to that which lies on the outer surface of the parietal crest. This bone bifurcates each branch ending in the skin, probably by an opening to the exterior. This last bone is the *nasal*: the former may be called the supra-temporal bone. (*See* Fig. A on the following page.)

It follows of course from the peculiar modification of the frontal bones that the cephalic portion of the lateral tube on the left side, following the course of the left frontal bone, passes from the apparent left side of the head to the right: morphologically of course it retains its proper relations, but as it passed originally dorsal to the left eye, it has been pushed over by the movement of that eye to the right side, and so comes to lie to the right of the anterior part of the dorsal fin. But the left nasal bone is on the left side, for the tube after leaving the left frontal bone bends beneath the anterior dorsal interspinous bone, to the left side of the snout: thus the left nasal bone is attached to the skin in front of the nasal capsule of the left side. The right nasal bone lies in front of the nasal capsule of the right side.

The supra-temporal bone, besides its posterior and anterior openings, has two others, a dorsal and a ventral. The dorsal opening is at the end of a short branch, and leads into a tube in the derma surrounded by modified scales, and in all respects resembling the tube of the lateral line: this supra-temporal dermal tube in fact lies under and is the cause of the supra-temporal branch of the lateral line described with the external

features of the sole. The ventral opening of the supra-temporal bone leads into a membranous separate tube, which passes beneath the skin in a ventral direction, runs through a tube which pierces the preopercular bone, and is continued forwards to the mandible.

Now the supra-temporal tubes are, as we have seen, dermal, and pass through apertures in a series of scales similar to those of other parts of the skin in structure. On the right side the supra-temporal tube retains this structure throughout up to its termination at the extreme apex of the snout. But on the left side anteriorly the scales disappear, and the supra-temporal tube opens out on to the surface, its sense organs becoming quite superficial: they are situated between the bases of the tactile filaments of the lower surface of the snout.

In the cod (*Gadus morrhua*) the lateral cephalic tube gives off another branch

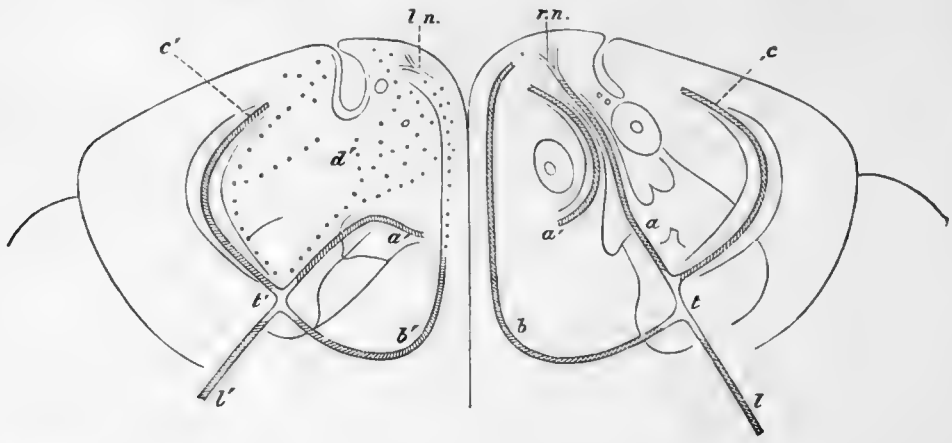


Fig. *A*. A diagram to illustrate the distribution of the epidermic sense-organs and dermal tubes on the head of the sole. *a*, the anterior continuation of the lateral tube; *b*, the supra-temporal tube; *c*, the preopercular tube; *d'*, the sub-ocular organs of the left side; *l*, the lateral line tube; *r.n.*, right nasal bone; *l.n.*, left nasal bone; *t*, the supra-temporal bone.

besides those already mentioned, namely a sub-ocular tube, which is enclosed by a series of scale-like bones, the sub-orbital bones. This sub-ocular branch is found in the plaice (*Pleuronectes platessa*) on the right side as a canal in the derma beneath the ventral eye; while on the left side it exists as a dermal tube between the mouth and the supra-temporal tube. In the sole I have been unable to find a trace of the sub-ocular tube on the right side, but on the left side it is represented by superficial epidermic sense-organs distributed all over the skin between the cleft of the mouth and the sense-organs of the supra-temporal line. In the sole there are in addition a number of superficial sense-organs along the line of the pre-opercular tube, forming a single series along the upper part of that tube, and spreading out over the whole area behind the mouth-cleft below.

The lateral cephalic tube and the pre-opercular tube, which are to a large extent enclosed in solid bone, nevertheless communicate at intervals with the exterior by

means of short tubes which open on the surface of the skin; the supra-temporal and sub-ocular dermal tubes where they exist, are also connected by short tubes with superficial pores, so that all the tubes of the system are related to the skin in almost the same way as the tube of the lateral line. The cephalic tubes also in all probability contain sense-organs similar to those of the lateral tube. The tubes of the head are innervated by branches of the cranial nerves. The supra-ocular part of the lateral cephalic tube receives branches from the orbito-nasal nerve, the sub-ocular tube is innervated by branches from the maxillary and palato-nasal nerves, the pre-opercular tube is supplied from the seventh or facial nerve. There is little doubt that the lateral and pre-opercular cephalic tubes, now enclosed in solid bone, were, like the rest, originally dermal tubes enclosed by tubular scales. In fact, the bones through which they pass represent dermal scales fused together. The tubes and the bones thus produced have sunk beneath the skin, and the bones have become part of the skull.

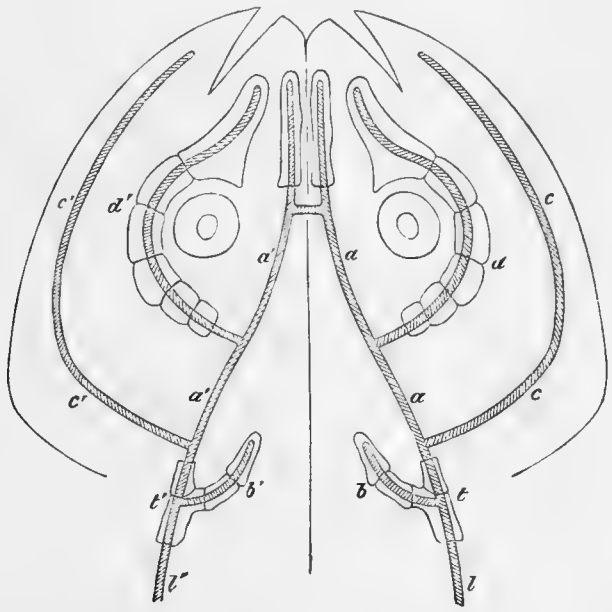


Fig. *B*. A diagram to illustrate the distribution of the dermal tubes in the head of the cod. Letters as in the diagram of the sole.

But all these dermal tubes at a still earlier period were part of the external surface of the skin. The sense-organs of the tubes and their epithelium are really derived from the epidermis. In some cases the organs of the lateral line are superficial throughout life, for example, in the gobies and the mullet, and in all cases they are developed in the embryo or young fish in the external epidermis. The tubes are formed both in evolution and development by the deepening and ultimate enclosure of grooves on the surface which include the sense-organs.

In the cod, which may be taken as exhibiting pretty nearly the original condition of the cephalic tubes of the sole and other flat-fishes, there are no superficial sense-organs on the head, and the tubes of the two sides are symmetrically arranged.

The diagram, Fig. *B*, shows the position and the relations of the cephalic tubes in that species. The supra-temporal tubes are short, and are surrounded by thin tubular scale-like bones. The sub-ocular tube is also enclosed in a series of tubular bony scales, the sub-orbital bones. Both these and the supra-temporal bones, though homologous with the ordinary dermal scales, are not similar to them, having a much larger size and deeper position.

In the sole the changes which have taken place in the course of evolution are as follows: The supra-temporal tubes have become much elongated, having grown forwards with the anterior extension of the dorsal fin till they reach the extremity of the snout. On the right side the tube is no longer enclosed by peculiar scale-like bones, but by tubular dermal scales, closely resembling the ordinary scales of the skin. On the left side of the head, the scales having disappeared anteriorly, the supra-temporal tube has opened out on to the surface, and the sense-organs which belong to it have become superficial. The two supra-temporal tubes are symmetrical in relation to the two sides of the dorsal fin, but entirely asymmetrical in relation to other parts of the head; for in consequence of their relation to the fin they both lie morphologically ventral to the left eye, between the left eye and the mouth.

The lateral cephalic tube of the left side has been distorted by the change of position of the left orbit. Its posterior part retains its original position, but its anterior or supra-ocular part lying in the inter-orbital process of the left frontal bone, bends round towards the right side and runs close beside the right supra-ocular tube between the two eyes.

The sub-ocular tube of the right side has disappeared; that of the left side is represented by the numerous superficial sense-organs which lie above the mouth on the lower side of the head.

The two pre-opercular tubes remain in their original position, but on the left side a number of superficial sense-organs have been developed over the region of the pre-opercular tube. This is, in some respects, one of the most remarkable of the peculiar developments in the head of the sole. It is intelligible that a dermal tube originally derived from a superficial groove should again become superficial; but it is surprising to find surperficial organs developing anew, outside a tube which contains similar organs originally derived from the surface.

The supra-temporal tubes are innervated by a long branch from the lateral nerve belonging to the vagus. On the left side a similar branch of the vagus passes forwards towards the sub-ocular sense-organs. Along the proximal part of the course of this nerve is a single series of superficial sense-organs, which lies over the proximal part of the lateral cephalic tubes. I have not been able to decide whether this series really belongs to the sub-ocular series of the left side, or bears the same relation to the proximal part of the lateral cephalic tube as the pre-opercular superficial organs to the pre-opercular tube. In studying the relations of the mucous tubes and epidermic sense-organs in the head of the sole, I have been very greatly assisted by a paper by

Dr. Ramsay H. Traquair, published in 1865.* The sole is not considered in this paper, but the interpretation of the distribution of the organs and canals in this species is comparatively easy after Dr. Traquair's lucid explanation of the derivation of the arrangements found in other flat-fishes from the original symmetrical condition.

The diagram of the arrangement in the cod which I have given is copied, with slight modifications, from Dr. Traquair's; and my diagram of the arrangement in the sole is constructed on the same plan as his diagrams of the arrangements in the plaice and other species.

Minute Structure of the Skin, Dermal Tubes, and Sense-organs.

When thin sections of the skin are prepared and examined under the microscope, the derma is seen to be composed of a number of sheets and bands of felted fibres, as in Pl. XIV, 6. In my preparations no nuclei are visible in this tissue, but the pieces of skin were decalcified in weak nitric acid before they were cut, in order to remove the lime from the scales, and the action of the acid may have somewhat altered the condition of the fibrils. The scales, as seen in section, consist of thin laminæ lying one upon another; the laminæ are entirely homogeneous in structure, and seem to be simply sheets of the fibrous tissue which have been consolidated and then impregnated with calcareous salts. The scales are contained in cavities of the fibrous tissue. In the preparations the fibrous tissue is separated slightly from the surface of the scales, but this is doubtless due to the shrinking produced by the process of preparation, and in life the fibrous tissue is in contact with the surface of the scale. Above the scales there is a layer of delicate spongy fibrous tissue in which the fibres are short, and run in a vertical as well as a longitudinal direction; this reticular tissue contains numerous nuclei. This tissue separates the external surface of the scale from the dense fibrous laminated tissue, while the internal surface of the scale is in immediate contact with the latter. The epidermis consists of several, six or seven, layers of cells. At the base of the epidermis the cells are polygonal and as broad as they are high: each cell contains a large nucleus, which becomes deeply stained under the action of staining liquids. Towards the outer surface most of the cells become thin and flat, as in the human epidermis, but in preparations a certain number of them are large spherical vesicles. These are mucous cells. The surface of the sole as of most other fishes is, during life, always covered with a certain amount of slimy mucus which is derived from the epidermis. This mucus is produced by the discharge of the contents of the globular mucous cells just mentioned. The cells at the base of the epidermis are constantly multiplying and growing, and in consequence the outermost of them are gradually pushed to the surface. The superficial layers are as constantly broken down and, as it were, dissolved away, some of the cells becoming, before they reach the surface, converted into capsules of mucus, and this mucus, together with the

* "On the Asymmetry of the Pleuronectidæ, as elucidated by an Examination of the Skeleton in the Turbot, Halibut, and Plaice." ("Trans." Lin. Soc., vol. xxv.)

débris of the other superficial cells, forms the slimy coating of the fish's skin. There are no special glands connected with the skin of the sole.

In the outermost layers of the fibrous derma, immediately beneath the epidermis, are situated the pigment cells or chromatophores. Some chromatophores are also found in a deeper position, in the fibrous tissue which lies between the deeper parts of the scales, but no pigment is found below the level of the skin to which the anterior edges of the scales reach. The epidermis and the thin subjacent layer of the derma, which contains the chromatophores, are continued over the exposed portions of the scales, with the exception of the longest most posterior spines of the scales: these pierce through the skin and epidermis and project beyond the latter.

The appearance of a longitudinal section through the dermal tube of the lateral line, magnified 40 times, is shown in Fig. 6, Plate XIV. In other parts of the skin muscles are of course found below the derma, but the dermal tube of the lateral line lies directly above the connective tissue partition between the dorsal and ventral lateral muscles, and the connective tissue of this partition passes directly into the skin. The fibrous tissue of this partition contains large spaces occupied by loose reticular tissue the meshes of which are large and filled during life with lymph; this tissue is seen in the lowest part of the figure. The figure includes one whole scale of the lateral line and parts of two others; the three pores, *p*,*p*,*p*, corresponding to these scales are seen leading into the dermal tube. The section passes longitudinally through the centre of the dermal tube and therefore the roof of the tunnel formed by each scale is seen above the dermal tube, and the floor below it. The dermal tube is seen bending down to pass through the hole in one scale to enter the tunnel of the scale behind it; beyond the hole in the floor of the scale a branch of the dermal tube passes backwards to open on the surface at the external pore. The dermal tube is lined by an epithelium which is only separated from the surface of the scales by a very thin fibrous membrane. This epithelium is continuous with the epidermis at the external pores, but differs much from the epidermis in character. It is of very slight thickness, consisting only of two or three layers of cells. The lowest layer consists of small undifferentiated cells which grow and multiply, continually replenishing the outer layers. Nearly all these outer cells are globular and vesicular; that is they form hollow capsules, doubtless containing mucus. During life the dermal tube contains mucus, which is the product of this epithelium. But at certain places this epithelium contains sense-organs, consisting of portions of the epithelium which have an entirely different structure and function. The cells of the sense-organs are not secretory but sensory, and they are connected with nerve fibrils. One of these sense-organs, as seen in longitudinal section, is shown at s.o, in Pl. XIV, 6. It is situated on the inner wall of the dermal tube, and lies on the floor of the tunnel of a scale a little in front of the hole through which the dermal tube passes to the next scale. At a point near the anterior and deep border of the scale containing the sense-organ there is a small aperture in the scale through which a nerve passes from the skin below the scale.

This nerve (n, Fig 6) runs posteriorly along the surface of the scale, beneath the epithelium of the dermal tube, to the sense-organ. The sense-organ consists of a number of thin elongated cells placed so that their length is almost perpendicular to the wall of the dermal tube. Each of these cells contains in its lower portion a spindle-shaped swelling which contains a nucleus. One end of each cell reaches the surface of the sense-organ, and the other reaches its basement membrane: the cells are all in contact, the nuclear swellings being so arranged that the cells are packed in the least possible compass. Thus the nuclear swelling of one cell is at its base, that of the next somewhat higher up, so that the nuclei form two rows, and the nuclei of some of the cells are even higher still, forming a third row. But it is only the nuclei which are in two or three layers, the cells are all in a single layer side by side. The nuclei, in spite of the arrangement described, occupy more space than the cells, and consequently the base of the sense-organ is broader than its surface, so that only the central cells are straight, the external cells curving at their upper ends towards the centre of the sense-organ. The upper end of each cell ends in a delicate protoplasmic hair which projects into the cavity of the dermal tube. The lower end of each cell is continuous with one of the ultimate fibrils of the nerve previously mentioned. I have not made out this connection in all the cells, but I have traced it in some, and believe that it exists in all. In some preparations a kind of clot is seen on the surface of the sense organ, and sometimes this seems to have separated from the surface of the organ, breaking off the sensory hairs and taking them with it. This clot often present a laminated appearance, as if formed of thin layers one over another. It has been seen in some fishes in an organ examined in a perfectly fresh condition. Prof. Emery* concludes that the laminæ of the clot, which is generally called the cupula, are successive cuticles secreted by the peripheral cells of the sense organ. I think it is difficult to accept this conclusion, and am inclined to think the cupula is, during life, of a mucous nature, and therefore semi-liquid. It seems certain that the sensory hairs are imbedded in the cupula. It is difficult to understand how such cells as those of the sense-organ should secrete mucus or form a cuticle: perhaps the cupula is nothing more than the ordinary mucus of the dermal tube which keeps a constant position in preparations because it is retained by the numerous sensory hairs.

There is not a sense-organ to every scale of the lateral line; in the middle of the body there is a sense organ on every third scale, that is to say, there are two scales bearing no sense-organs between two scales which bear them. The position of the sense-organ in relation to the scale on which it is situated is always the same.

The function of these sense organs is still entirely unknown. It has been suggested that they convey to the fish a sense of its position in the water, and so enable it to retain its vertical position, but the evidence for this is not very conclusive: if it were true we should expect to find the organs atrophied in the flat fishes which have

* "Fauna und Flora des Golfes von Neapel," "Fierasfer."

abandoned the vertical position altogether. What stimulus affects the organs it is difficult to imagine: and it is also difficult to understand how the sensory hairs act immersed as they are in the substance, whether it be mucus or not, which forms the so-called cupula. But that these organs are of great importance to aquatic vertebrates there can be no doubt, since they occur not only in all kinds of fishes but in aquatic Amphibia: they are even present in the tadpole and other larval batrachians so long as they retain their aquatic respiration.

These sense-organs are in all cases first developed in the superficial epidermis; the development of the dermal tube in which they are enclosed takes place subsequently. The dermal tube is formed from a superficial groove which appears on the surface of the skin along the line where the sense-organs are situated. The groove becomes deeper and its edges meet over it and coalesce everywhere except where the pores are left by which the tube communicates with the exterior. In some fishes, *e.g.*, Gobius, the sense-organs remain superficial throughout life, no lateral dermal tube being developed.

As I have already mentioned (p. 76) there are also a number of superficial sense-organs on the under side of the head of the sole. These organs are situated in the depressions between the villi or tactile filaments with which the skin in this region is provided. The minute structure of this part of the skin is illustrated by Fig. I, Plate XV, which is drawn from a section of the part of the skin above the posterior half of the mouth cleft on the lower side of the body. Some of the filaments are long and slender, others short and blunt. Running up the centre of each filament is a sausage-shaped supporting rod which is composed of a tissue having the structure of fibro-cartilage. In section this body exhibits fibres anastomosing with one another and running in a direction transverse to the longer axis of the rod. These fibres contain nuclei, and the interspaces between them are filled by a homogeneous solid substance of the nature of cartilage. These supporting rods belong to the derma. The epidermis is continued over the filament, becoming thinner at the apex, and between the supporting rod or core and the epidermis is a continuation of the fibrous tissue of the derma. Running up the sides of the supporting rod are several fine nerves. These nerves send off fibrils which branch, and their ultimate ramifications enter the epidermis. There are no special sense-organs of any kind in connection with these nerve fibrils: the ultimate termination of the fibrils I have not been able to trace: they penetrate between the cells of the epidermis, and doubtless ultimately come into connection with some of the epidermic cells. Nerve-fibrils are known to enter the epidermis in the same way in the skin of the tip of the human finger, and in all probability help to give that skin its delicate sense of touch. I have indicated the connection of the ultimate nerve-fibrils with the epidermis on the right side of the figure. On the left side of the figure are sections of four short blunt filaments which do not project far beyond the surface of the skin. Around the cores of these, besides the black lines indicating parts of nerves, is a coarse stippling which represents the appearance of a curious granular

tissue occurring in this position in all the filaments. This tissue obscures the nerve fibres and makes it somewhat difficult to follow out their course in the sections. The sections from which the present description is taken, and one of which is represented slightly diagrammatically by the figure, were prepared from pieces of skin treated when fresh with chloride of gold. This reagent stains the nerves black or violet, and affects the remaining tissues slightly or not at all. Thus the nerves can be traced through the granular tissue just mentioned. The granular tissue is somewhat opaque, consisting of irregularly branched cells the contents of which are coarsely granular. These cells exactly resemble in structure the chromatophores of the right or coloured side of the body, but they are not coloured. In fact, to use a seeming paradox, these cells are colourless chromatophores; that is to say, they are chromatophores of which the granules instead of being black or orange are white and opaque. Thus the white colour of the under side of the sole is not due to the absence of chromatophores, but merely to the absence of what is usually called colour in the chromatophores; the pigment cells are not absent from the skin of the lower side, but are bleached. It is a very common thing to find coloured blotches on the lower side of a sole, and from the above it is evident that these coloured blotches are not due to the development of chromatophores in certain areas while they are absent elsewhere, but are due to the fact that the chromatophores in these areas are coloured, while in the rest of the skin of the lower surface they are white.

One of the superficial epidermic sense-organs of the under side of the head is represented in section in the figure. It will be seen that they do not differ in structure from the sense-organs of the dermal tube of the lateral line. The sensory hairs are present in these organs, though not shown in the figure, as they are not well preserved by the chloride of gold method of preparation.

CHAPTER VI.

EMBRYOLOGY.

The ripe ovum of *Solea vulgaris* after it has been removed from the body of the fish and is floating in sea water, and when it has not been fertilised, has the following structure: The whole ovum is a spherical transparent body measuring 1·47 to 1·51 mm. (·05 to ·06 inch) in diameter, the size of different eggs varying within these limits. The ovum consists of a definite thin transparent membrane surrounding a solid mass; the former may be called the vitelline membrane, the latter the ovum in a stricter sense of the word. The whole of the egg with its envelope corresponds only to the yolk of a hen's egg, there is nothing about it which represents the "white" or the shell of the latter. The yolk of a hen's egg is surrounded by a thin membrane of its own which corresponds to the vitelline membrane of the sole's egg. The ovum proper within the vitelline membrane consists of two different parts: a smaller somewhat protuberant portion which is more granular and less transparent, and a more transparent larger portion. The former is the germ (blastodisc), and consists of living organic matter known as protoplasm. This germ is actually alive, and it exhibits spontaneous movements and changes which gradually lead to the formation of the young fish, while the larger portion is the yolk, and is simply a supply of very nutritious food on which the germ lives and by means of which it grows. The yolk is in fact gradually absorbed by the embryo during its development. In consequence of the protuberance of the germ, the vitelline membrane being stiff and spherical, there is a space between the membrane and the surface of the ovum all round the junction of the germ with the yolk: this is the perivitelline space. Immediately beneath the germ the yolk is divided up into large separate masses of a cubical shape: these masses form a single layer, the rest of the yolk being undivided. The yolk is more or less liquid, and it is confined within a delicate pellicle of protoplasm which extends from the edge of the germ all round the yolk. Thus the yolk is really contained within the protoplasmic germ. In fact the germ is the essential part of the ovum; some animals produce ova without either membrane or yolk: the yolk is to be regarded as an accumulation of food material within the protoplasm of a reproductive "cell" or plastid. On the surface of the yolk, immediately beneath its protoplasmic pellicle, are several groups of minute oil globules. On account of their refracting power these appear

opaque white by reflected light and dark by transmitted light. They represent an excess of fatty matter belonging to the yolk.

I have not seen the ripe ovum of the sole immediately after its escape from the ovary. But the ova of other flat-fishes have been studied by myself and others immediately after extrusion, and it has been found, *e.g.*, in the cod and the flounder, that at first the germinal protoplasm is not aggregated into a protuberant mass, but is more extended over the surface of the yolk, and that the vitelline membrane is everywhere in direct contact with the ovum. The aggregation of the protoplasm into a distinct germinal mass and the consequent formation of the perivitelline space take place after the extrusion of the ovum, and take place in the same way whether the ovum is fertilised or not.

I have not particularly studied the spermatozoon of the sole, but have observed it sufficiently to state that it does not differ in structure in any important respect from that of other flat-fishes. The milt is very scanty in quantity and thin and transparent in appearance, but its peculiarities will be considered in connection with the subject of the artificial propagation of the species. I have given a figure of the spermatozoon of the dab, *Pleuronectes limanda*, Pl. XIII, 7, having accidently omitted to make a drawing of that of the sole. In all bony fishes (Teleostei) the head of the spermatozoon is pear-shaped, the pointed end being directed forwards in motion. The long slender vibratile filament or "tail" is attached to the broader end of the head. The spermatozoa are exceedingly small, quite indistinguishable to the unaided eye, but when the fresh milt is placed under the microscope multitudes of them are seen actively lashing themselves about in all directions. The total length of a spermatozoon of the sole is about $\frac{3}{1000}$ths of an inch (·07 mm.).

Fertilisation of the ovum usually takes place immediately after extrusion, and consists in the entrance of a single spermatozoon into the germinal protoplasm. I have not studied the details of the process in the sole's ovum, but have done so in the ova of the dab (*Pleuronectes limanda*) and another species (*Pl. cynoglossus*). The process in the sole is doubtless the same as in these species, and is as follows: Over the centre of the germinal protoplasm there is a minute aperture in the vitelline membrane which is called the micropyle. Through this aperture a spermatozoon passes, and penetrates into the germinal protoplasm. In the latter is the nucleus which, as the ovum matures, becomes indistinct, and can only be made visible by coagulating the protoplasm with acetic acid or some other chemical reagent. This nucleus can also be stained, as it absorbs colouring fluids, such as solutions of carmine, to a greater extent than the surrounding protoplasm. The nucleus before fertilisation is complete passes to the surface of the germ and gives off in succession two small portions of itself, the polar bodies, which are expelled from the ovum. The nucleus after this forms the female pronucleus, and the head of the spermatozoon which has entered the germ forms a similar minute body, the male pronucleus: these two unite into a single nucleus, the segmentation nucleus

The fertilised ovum of the sole, then, possesses the same structure as was above described in the unfertilised, and also something not mentioned in the previous description, namely, a nucleus in the germ formed by the coalescence of two pronuclei, one derived from the nucleus of the unfertilised egg, the other from the head of a spermatozoon.

The first visible change which takes place after fertilisation is the division of the germinal mass into a number of small segments. The mass first divides into two halves separated by a superficial furrow extending across its middle. Another furrow then appears crossing the first, so that the mass is divided into four portions. Each of these divides again into two and then into four, so that there are now sixteen segments. Then divisions take place in a direction parallel to the surface of the mass, so that it comes to consist not of one layer of segments, but of several layers. As this process of segmentation continues the segments continually become smaller, so that the condition is reached which is seen in Plate XV, Fig. 3. During this time movement of the protoplasm on the surface of the yolk and between the yolk segments has caused the latter to extend somewhat beyond the edges of the germinal mass.

The mass of protoplasmic segments into which the original single large mass has thus been converted now begins to become thinner and broader, extending itself so as to envelop the yolk, as in Plate XV, Fig. 4. When this process begins a cavity is formed between the yolk and the central part of the germinal mass. The germinal mass as it extends over the surface of the yolk soon becomes so thin that it must now be called the germinal membrane (blastoderm). Fig. 5 shows the stage at which the germinal membrane has enveloped more than half the yolk. The external part of the germinal membrane for some distance from the edge is thicker than the central portion: this thicker portion rests upon the yolk, while the central part is separated from the yolk by the flat cavity already mentioned. This cavity is not exactly in the centre of the membrane, the thicker external ring extending farther inwards (on the right of Fig. 5) at one point than elsewhere: this broadest part of the germinal ring is also the thickest part, and it forms the rudiment which will give rise to the upper or dorsal part of the body of the young fish. It must be observed that the layer of yolk segments extends *pari passu* with the germinal membrane, and that the patches of oil globules are always at the edge of the extending membrane.

As the germinal membrane continues to extend the circumference of the germinal ring of course gets smaller; the rudiment of the young fish above mentioned remains with its internal extremity in the same position, continually increasing in length as the edge of the membrane extends over the yolk, until when the yolk is completely enclosed, the whole of the germinal ring has been taken up into this rudiment. The dorsal rudiment by this time has become much thicker and forms an almost cylindrical rod, from the sides of which the germinal membrane extends over the yolk. The oil globules are now arranged beneath the sides of the dorsal rudiment, while the yolk

segments form a layer extending over the whole surface of the yolk. The end of the rudiment which was originally turned towards the centre of the germinal membrane becomes enlarged and forms the head of the fish; the point where the edges of the membrane closed together forms the posterior end. After a short time two spherical masses are seen defined in the head of the embryo: these are the first rudiments of the eyes. The centre of the dorsal rudiment begins to be divided by transverse divisions into segments: these segments are blocks of tissue which will afterwards form the large lateral muscles of the fish. At the tail end a small round cavity appears, which afterwards becomes part of the cavity of the intestine. These various structures are seen in Plate XV, Fig. 6, and Plate XVI, Fig. 1, one of which shows a profile, the other a ventral, view of the embryo at the stage now described.

At this stage scattered black dots have appeared on the external surface of the dorsal rudiment, extending out over the surface of the yolk some distance from the sides of the latter. These are pigment cells, and are situated in the skin: they are usually called chromatophores.

What I have called the dorsal rudiment is the solid dorsal portion of the young fish containing the rudiments of the brain and spinal cord, of the backbone below these, and of the lateral muscles at the sides. The yolk sac represents the abdomen of the young fish. The intestine is formed as a simple tube beneath the dorsal rudiment resting on the surface of the yolk. It is at first closed at each end, neither mouth nor anus being yet formed

After this stage a cavity appears at the anterior end of the embryo between the germinal membrane and the yolk. The segmentation cavity previously described ceased to be visible after the envelopment of the yolk by the germinal membrane, the latter having come into contact with the former. The cavity which now appears has exactly the same position as the segmentation cavity. The embryo grows out posteriorly, forming a tail which is independent of the yolk sac. The black chromatophores increase in number and extend over the whole surface of the yolk sac, at the same time they become branched, sending out short branches in all directions so as to assume a stellate form. Other chromatophores also appear in addition which are of a yellow colour, appearing darker when seen by reflected light. These changes are seen in Plate XVI, Fig. 2.

As the tail increases in length a fold of the skin is formed in the middle line along its dorsal and ventral edge; the dorsal fold extending to the head of the embryo. The other changes which have taken place by the time the young fish is hatched will be understood by reference to Plate XVI, Fig. 3, which shows the fish immediately after hatching. The yolk is now considerably diminished and the intestinal tube opens behind it by the anus. The tail measured from the anus is as long as the distance from the anus to the front of the head. The wide membranous fold is seen extending along the middle ventral line of the tail and along the median dorsal line of the fish to the back of the head: this is the primordial median fin. There is still no mouth.

Behind the eye is a small oval cavity containing two specks. This is the primitive ear, the black specks being small particles of carbonate of lime formed within the auditory cavity. Beneath the throat is seen a small tubular structure, which in the living young fish pulsates regularly: this is the heart. From the line where the wall of the yolk sac, or abdomen, joins the body there projects a semicircular membranous fold, which is the beginning of the pectoral fin. No indication of the pelvic fins is yet present. The trunk of the young fish is seen to be divided by a series of curved transverse lines: these are the divisions between the muscular masses of which the trunk muscles are composed. A kind of tube runs down the centre of the body, the contents of which show a recticulate structure. This tube is the notochord, which contains gelatinous material in a number of cavities divided from one another by thin partitions like the cavities of a sponge. No bone is yet formed, but the vertebræ when they develop arise as a series of bony rings formed round the notochord. The chromatophores are now much more abundant than in the embryo before hatching; there are still only two kinds, the black and yellow, and both are much branched; the two kinds are everywhere mingled together. The pigment is abundant in the primordial median fin, except at its posterior extremity.

Fig. 4 is a drawing from another recently-hatched sole, a few hours older than that shown in Fig. 3. It will be observed that this figure shows the left side of the fish, while Fig. 3 shows the right side, and that the two sides correspond in all respects. The newly-hatched sole, or larva of the sole as it may be called, exhibits perfect bilateral symmetry and therein resembles the adults of the greater number of marine fishes. In Fig. 4 the olfactory organ is seen in front of the eye: it is on each side a simple rounded cavity opening by a small aperture to the exterior.

It may be explained here, though it is not evident in the figures, that the cavity surrounding the yolk in the larval sole contains primitive blood; this primitive blood contains minute colourless corpuscles, but no red corpuscles, which are not formed till a later stage. The posterior end of the heart is open to this cavity, and the blood is propelled from the cavity along the vessels at the side of the throat into the aorta which runs beneath the notochord, and from the aorta to the cavity again.

The newly-hatched larva is from 3·55 to 3·75 mm. in length (·142 to ·15 inches), or between one-seventh and one-sixth of an inch, and about two and-a-half times as long as the diameter of the ovum.

Up to this point the stages of development have been described as they are seen in the living egg or newly-hatched fish, and all the figures referred to are from drawings made by the aid of the camera lucida with a low power of the microscope. But, although I have not studied the subject especially in the egg of the sole, it will be convenient here to give a brief description of the internal processes of development so far as they are known to occur in the eggs of fishes.

The germinal ring when examined by means of prepared thin sections is found to consist of three layers of cells. The outermost, which is two cells thick, is called the

epiblast, and gives rise to the epidermis and other organs, the innermost, which is only one cell thick, is called the hypoblast, and gives rise to the intestine, the middle layer is called the mesoblast, and gives rise to the bones, muscles, and blood vessels. In the dorsal rudiment the same three layers are found, but the epiblast is here thickened into a great keel which extends inwards and causes the projection of the rudiment; the greater part of this keel ultimately separates from the extreme outer layer and forms the brain and spinal cord. In the centre of the rudiment beneath the keel is a cylindrical rod of cells which become converted into an elastic supporting structure, the notochord. Round the yolk, when it has been completely enveloped, there is a layer of protoplasm containing nuclei, but not divided up into cells. The hypoblast rests on this layer which is called the periblast. In the ventral region of the developing embryo there is nothing but epiblast separated from the periblast by the flattened cavity previously mentioned and called the segmentation cavity. The hypoblast bends round and forms a straight tube which lies in a depression in the periblast. This tube is the intestine, and when first formed has neither anterior nor posterior opening, neither mouth nor anus. The swelling of the anterior part of the epiblastic keel forms the brain and causes the protuberance of the head. The sense organs are formed by thickenings of the epiblast: these thickenings become hollow and globular and, sinking into the interior part of the head (except the nasal organs), become connected with the brain by the sensory nerves. The nasal organs become cup-shaped, their cavities being open to the exterior by a single aperture each, which is ultimately divided into two, the two nostrils of each organ. The heart is formed from mesoblast which extends below the front part of the intestinal tube; it opens posteriorly at first from the segmentation cavity, but when the yolk is absorbed becomes connected with veins. The inner part of the mesoblast forms the muscles and skeleton, the outer part forms the fibrous layer of the skin in which the scales are produced. Rings of bone formed round the notochord give rise to the vertebræ, while the bones of the skull are formed from the mesoblast round the brain. The formation of the mouth and gills takes place after hatching by the development of rods of cartilage between which clefts appear placing the anterior part of the intestine in communication with the exterior. The mesoblast on each side splits horizontally, its inner thinner layer remaining attached to the intestine to form the muscles and fibrous tissue of the gut, while the outer part forms the body muscles. The cavity thus formed is the body cavity, and at the dorsal part of it are formed the kidneys and reproductive organs. The liver is formed as an outgrowth from the intestine. The fins are merely folds of the skin, the mesoblast of which gives rise to their muscles and bony rays.

I have not succeeded in obtaining any specimens of the young sole in process of metamorphosis; the next stage in which I have met with it is that of a small fish having in almost all respects the same structure as the adult. The smallest specimens of this kind which I obtained were from $\frac{1}{2}$ in. to $\frac{5}{8}$ in. in length (12 to 15 mm.). One of them is represented in Plate XVI, Fig. 5, magnified $8\frac{1}{4}$ times. The great

similarity of the young sole at this minute size to the full-grown adult is evident from the figure. The chief difference is in the relations of the intestine. The right lateral diverticulum of the body cavity is scarcely at all developed, and the four lengths of intestine which occupy that diverticulum in the adult are absent. The intestine extends backwards only very slightly beyond the anterior ventral interspinous bone. The dorsal eye is slightly nearer to the edge of the head than in the adult, otherwise the metamorphosis is complete. The colour has disappeared from the lower side, the markings of the species are completely developed on the upper side. The pigmentation of the upper side is not nearly so dense as in the adult, and the whole body is somewhat translucent, but nevertheless when the young fish is seen in the living state by reflected light, whether resting on the bottom or swimming horizontally in the water, its upper side shows the same colour as the adult, and undergoes the same changes of colour on different materials in consequence of the action of light. The identification of the young sole, *Solea vulgaris*, at this stage is neither doubtful nor difficult, for, although some of the characters of the adult are not discernible, others can be perceived easily enough. The large number of anal fin rays distinguishes it from either *S. variegata* or *minuta*, while the tubular form of the anterior left nostril distinguishes it from *lascaris*. I obtained specimens of this stage on three occasions within a short time, in 1889, from the shore at low water at spring tides. On the third occasion I received only one specimen which was nearly three-quarters of an inch long (18 mm.).

I could not trace the further development of these young soles, for they disappeared from the shore. But no important changes of structure were required to produce the adult, further development consisted almost entirely in the increase of size. For the discussion of the later growth reference must be made to the next part of this memoir.

The only other species of *Solea* whose development I have been able to study is *S. variegata*. The eggs of this species are smaller than those of *vulgaris*, measuring 1·28 to 1·36 mm. in diameter. The egg, Plate XVI, Fig. 6, is easily recognised and distinguished from that of *S. vulgaris* by the peculiarity of its oil globules, which, instead of being very minute and numerous and aggregated in a number of distinct groups, are of considerable size and scattered singly and separately all over the surface of the yolk. The external layer of segmented yolk is present as in *S. vulgaris*. The development of course takes place in the same way as in the latter. When the chromatophores appear they form another distinguishing feature; there are both yellow and black chromatophores as in *vulgaris*, but the former are much lighter in this species, inclining to lemon colour, while those of *vulgaris* are darker.

Figs. 1 and 2 on Plate XVII show two stages of the hatched larva of the "thick-back." The younger, Fig. 1, immediately after hatching, has of course the largest yolk-sac and the shortest length of body; it is 2·42 mm. in length. The heart is just visible, but is compressed between the yolk and the under side of the throat, the pericardium being but slightly developed and scarcely visible. The stage shown

in Fig. 2 is that of a larva two days after hatching; the larva from which the figure was taken was 2·52 mm. in length.

The eggs of the other species of *Solea* I have not yet seen, but for the sake of comparison I have illustrated the development of several species of flat-fish. Figs. 3, 4, 5, Plate XVII, and Fig. 1, Plate XVIII, represent a series of stages in the development of the common flounder, *Pleuronectes flesus*, from the time of hatching till the completion of the metamorphosis. Fig. 3, Plate XVII, is from a larva hatched under artificial conditions on February 18, 1889, and drawn two days afterwards: its length was 3·56 mm. The chromatophores are arranged in such a way as to form two transverse bands, one at the level of the anus, the other some distance behind it; two dark bands in these positions are more or less conspicuous in several species of Pleuronectes in the adult condition. Fig. 4 shows the same larva when the yolk has been entirely absorbed and the mouth and gill-slits have been developed: its length was 3·94 mm. The pectoral fin is relatively very large at this stage. This condition was reached in confinement on February 24, by larvæ hatched on February 18. The next stage was observed in young fish found in the harbour at Mevagissey at low tide on April 2, and is represented in Fig. 5. The length of the fish from which this figure was drawn was 10·5 mm., or a little over three-eighths of an inch. This stage is the beginning of the metamorphosis. The left eye has travelled upwards so as to project above the edge of the head, but it is still on the left side. The little fish in this condition swims on its edge, but slightly inclined to the left side. It is still extremely transparent, so that when alive it is only rendered visible by the metallic brilliancy of the choroid coat of the eyes, which shine through the transparent tissues in the sun like two metal beads. The yellow spot in the visceral cavity in the figure is the gall bladder. Fig. 1, Plate XVIII, shows a later stage in which the left eye has reached the edge of the head, so that its lens and cornea are visible on the right side. The fish from which this figure was taken was actually smaller than that represented in Fig. 5, Plate XVII, probably because its metamorphosis had begun somewhat earlier. It seems that in some individuals the metamorphosis is completed while they are smaller in size than others at an earlier stage of development. The fish represented in Fig. 1, Plate XVIII, was exactly 1 cm. in length. It was much more opaque and more pigmented than the stage previously described; in fact, though slightly translucent when seen under the microscope by transmitted light, to the unaided eye it appeared quite opaque. It will be noticed that the interval of time between the stage of Fig. 4, and that of Fig. 5, Plate XVII, was about five weeks, and that in that time nearly all the organs had reached their final form. The muscles and skeleton have developed very greatly. The part of the body behind the anus has increased very much in dorso-ventral breadth, and in it the vertebræ with their spines, the interspinous bones, and the fin rays have been completely formed.

Fig. 2, Plate XVIII, represents the larva of the dab (*Pleuronectes limanda*) immediately after hatching. The larva from which this figure was taken was hatched in

the Laboratory from an egg artificially fertilised on March 1, 1889. The length of the larva was 2·87 mm. The development of chromatophores in the median fin fold does not take place in this species at so early a stage as in *P. flesus.*

Fig. 3 of the same Plate represents a stage in the development of *P. microcephalus*, the merry sole of the Plymouth fishermen, the lemon sole of Scotland and most parts of England. The larva from which this figure was drawn was also hatched in the Laboratory, and was four days old; a small quantity of yolk still remained in the body cavity. The chromatophores at this stage form five well-marked interrupted transverse bands.

Fig. 4 of the same Plate represents a larva of the plaice (*P. platessa*), just after the complete absorption of the yolk. This larva was also hatched in confinement: it was drawn on February 27, five days after hatching. The larva of the plaice is much larger than that of any of the other species here mentioned: at the stage figured it was 6·5 mm. in length.

Fig. 5 represents the appearance and natural size of a living larva of the brill (*Rhombus lævis*). The young of the turbot and brill remain pelagic until after the completion of the metamorphosis, that is, they swim about near the surface of the water, and are commonly met with in the still waters of inlets and harbours at the proper time of year, namely, in June and July. The one here represented was taken in Sutton Pool, Plymouth, on June 1. Their pelagic habit is correlated with the development of a relatively large air bladder, an organ which is entirely wanting in the adult. Although they swim freely in the surface waters they do not swim vertically when the right eye has migrated to the left side, but horizontally; during metamorphosis their inclination from the vertical in swimming is proportional to the degree of asymmetry of their eyes.

CHAPTER VII.

STRUCTURE OF *PHYLLONELLA SOLEÆ*, VAN BENEDEN AND HESSE, A PARASITE OF THE COMMON SOLE.

On the lower side of the sole are usually found specimens of a small parasitic flat worm which lives on the surface of the skin. This creature was first named and described by two Belgian zoologists, Van Beneden and Hesse, who called it *Phyllonella soleæ*. It is of flattened shape, the dorsal surface being slightly more convex than

Fig. C.

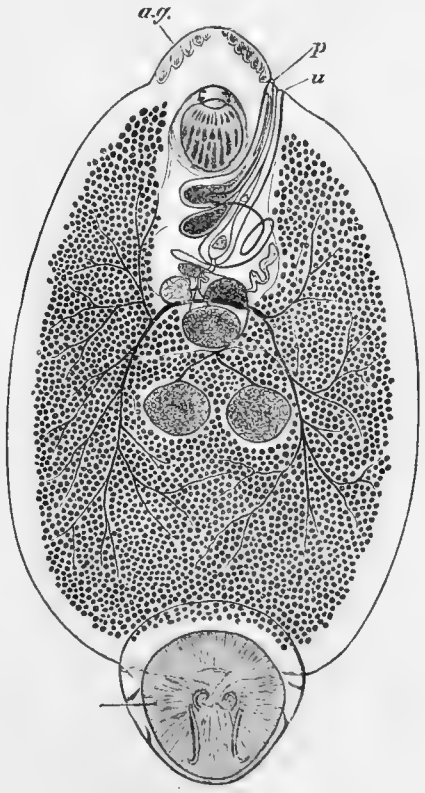


Fig. D.

Fig. C.—Egg of *Phyllonella soleæ*, seen under microscope in the fresh condition. Magnified 100 times.
Fig. D.—*Phyllonella soleæ*, the ventral side uppermost, magnified 17 times; *p.s.*, posterior sucker; *a.g.*, anterior glandular patches; *p.*, aperture of penis-sheath; *u.*, aperture of the uterus.

the ventral, and the outline of the body is an oval with projecting ends, so that its shape resembles that of a small leaf. The animal, when adult, is usually about one-fourth of an inch in length (6 or 7 mm.), and one-eighth of an inch (3 mm.), in greatest breadth, but young individuals are smaller, and larger specimens are often seen. The structure of this parasite is shown in the accompanying woodcut, Fig. D, which represents the appearance of a living specimen under the microscope. At the posterior end of the body is a large muscular sucker, *p.s.*, almost circular in shape: the concavity of this sucker is ventral, and it is attached to the body by a peduncle at about the middle of its dorsal surface. On the ventral side of the sucker are two pairs of hooks imbedded in the skin, with their recurved points protruding. One pair of these hooks are long and directed backwards, their points being near the posterior edge of the sucker, the other pair are short, and their points near the centre of the sucker. At the anterior end of the body there is a semicircular projection, the ventral edges of which are provided with a pair of glands, *a.g.*, for adhesion Behind this projection is the small mouth, and at the left hand side of the projection are the two genital apertures, *p.*, *u.*, close together. The worm crawls about on the skin of the lower side of the sole, anchoring itself to the spines of the fish's scales by means of its sucker and its hooks, and using the anterior glands for adhering by that end when it moves its posterior sucker from one position to another.

The most extensive and conspicuous organs are the generative, male and female, for the animal is hermaphrodite, and each individual produces both spermatozoa and ova. The digestive organs are small, consisting only of a sac-like organ into which the mouth opens, and which is lined by very large cells with enormous nuclei. This organ may be called the alimentary sac, since it presents no distinction of parts. In front of the alimentary sac dorsally are two simple nerve ganglia, giving off a main lateral nerve cord on each side, which passes backwards. In the skin above these ganglia, the cerebral ganglia, are two pairs of eyes, or rather pigment spots which are doubtless organs sensitive to light. The renal organs consist of a system of minute ramified ciliated tubes communicating with two main lateral tubes, which probably open by a single dorsal opening at the posterior end. The rest of the body consists of the generative organs, and a dense parenchyma of cells filling up the interspaces between the various organs.

Uniformly scattered throughout the parenchyma of the body are a large number of globular organs consisting of aggregations of peculiar cells: these are the yolk-glands. They are situated at the ends of the ultimate ramifications of a ramified system of tubes which are the yolk-ducts, and which are completely filled with granular globules similar to the contents of the cells of the yolk-glands. The yolk-ducts on each side of the body ultimately unite into a single large duct which opens into a sac situated a little to the left of the middle line, about one-third of the length of the body from the anterior end. This is the yolk-reservoir: it is elliptical in shape and transversely placed. The yolk-reservoir is filled with the same material as the yolk-ducts; the terminal yolk-ducts

which open into it on each side are ventral in position. The ovary is a flattened sac with a circular outline situated immediately behind the yolk-reservoir. It is filled with small spherical ova, each containing a large nucleus or germinal vesicle. In front of the ovary, dorsal to the right main yolk-duct, is a sac with the shape of a pyramid. Into this sac or vestibule open a short oviduct from the ovary, a short duct from the yolk-reservoir, and two minute short ducts from two spherical capsules containing spermatozoa. Here the egg is fertilised. From the vestibule the oviduct is continued for some distance as a narrow convoluted tube, which then suddenly expands into a thick-walled sac shaped like a club, the thick end being internal, and the thin end opening to the exterior on the edge of the body to the left of the anterior apex. This thick-walled sac may be called the uterus. The fertilised ovum in the vestibule is surrounded by a quantity of yolk, and the compound mass thus formed passes down the oviduct to the uterus, where it is surrounded by a chitinous hard shell produced from the wall of the uterus. The shell has the shape of a triangular pyramid, and its apex is prolonged into a long thin filament, swelling at intervals into bead-like globules. This filament is doubtless adhesive, and by it the egg when laid, Fig. C, is attached to the skin of the sole, there to develop into a young *Phyllonella*.

The primary male organs are a pair of globular testes situated a short distance behind the ovary, one on each side of the middle line. These testes are simple sacs, the walls of which are lined by cells which give rise to the spermatozoa. Some of these cells become free in the cavity of the testis, and undergo subdivision, each of them forming a spherical cluster of small cells, the spermatoblasts, each of which is converted into a spermatozoon. From the anterior surface of each testis passes off a tube or duct, the *vas deferens*; the two ducts unite just behind the ovary, and the single *vas deferens* passes round the left side of the ovary, and the left side of the yolk-reservoir, dorsal to the left main yolk-duct. In the part of its course which lies in contact with the yolk-reservoir the *vas deferens* is connected with a coiled sac closed at its farther end. This is a reservoir for the ripe spermatozoa, and must be called the *vesicula seminalis*. After a tortuous course the *vas deferens* opens into an intromittent organ, the penis. The mechanism of this organ I have not been able completely to elucidate. It consists principally of a club-shaped structure lying between the uterus and the alimentary sac. Along its outer half this structure contains a canal, which is at the side of it, not in the centre: into this canal the *vas deferens* opens, and by it the spermatic fluid is conveyed to the exterior. The inner half of the structure contains granular matter, but, as far as I can make it out, is not a gland. At the base of the penis is a pear-shaped structure with radiating bands in its interior, which converge into a band apparently of muscle, which seems to run into and become merged in the substance of the penis. I am inclined to think that these structures have something to do with the protrusion and retraction of the penis, but I am unable to understand how they act.

In the chief features of its structure *Phyllonella soleæ* resembles a number of other

external parasites of fishes which are classed in a family called the Tristomidæ. Most of these forms possess a small sucker on either side of the anterior end of the body as well as one large posterior sucker, hence the name of the family. The glandular areas described on the anterior end of *Phyllonella* represent the anterior suckers. The Tristomidæ belong to the order Trematoda.

PART III.

BIONOMICAL.

CHAPTER I.

GEOGRAPHICAL DISTRIBUTION.

The common sole is a somewhat southern species. In the neighbourhood of the British Islands it is found in considerable abundance all over the southern part of the North Sea, south of a line drawn from Flamborough Head in Yorkshire to the north-west coast of Denmark. North of this line it is scarce. It is occasionally taken off the mouth of the Firth of Forth, but very rarely. It is said to have been taken in the Moray Firth, and off the Orkney and Shetland Islands. On the east side of the North Sea it enters the Baltic, being occasionally taken on the north and east coasts of Denmark and the coasts of Schleswig-Holstein and Mecklenburg. Further east in the Baltic it has not been observed. Occasional examples have been taken on the west coast of Norway up to the sixty-fourth degree of north latitude—the neighbourhood of Trondhjem. It occurs in some abundance all round the shores of Ireland, and on the west coast of Britain from the mouth of the Firth of Clyde southwards, becoming more abundant towards the south. It is abundant in the Bristol Channel and throughout the English Channel, in the Bay of Biscay and southward along the west coast of Portugal. It extends throughout the Mediterranean and probably into the Black Sea. How far south the species extends along the coast of Africa I have not been able to ascertain: it is not mentioned in Lowe's "Synopsis of the Fishes of Madeira," 1837.

The other three species, *lascaris*, *variegata*, and *lutea*, are common to the south-west coast of England and the shores of Italy. In all probability they occur also along all the intermediate coast-line. *Lascaris* occurs also at Madeira, if the specimen called *lascaris* by Günther is to be considered as of the same species as the English form. *Solea impar*, Bennett, and probably *S. margaritifera*, Günther, both closely allied to *lascaris*, come from the Atlantic coast of northern Africa.

There are a large number of other species of *Solea* as here defined besides those which occur in Britain. There are several which exist in the Mediterranean, namely, *Solea Kleinii*, *Solea ocellata*, *Solea monochir*. One species is known from the west coast of Africa, viz., *Solea senegalensis*. On the west side of the Atlantic the genus is but slightly represented. One of the few things in which the citizens of the United

States of America confess that their country is inferior to Europe is that they have neither the sole nor the turbot in their seas. The only species of *Solea* on the northern part of the Atlantic coast of the United States is *Solea achirus*, Linnæus, a species with no pectoral fins, which grows to the length of only six inches, and is quite useless as food. *Solea inscripta*, Gosse, occurs at Jamaica. Other similar species, with pectorals rudimentary or absent, occur at the Keys of Florida. *Solea reticulata*, *Gronovii*, *maculipinnis*, *mentalis*, *Jenynsii*, in Dr. Günther's catalogue, are all forms with rudimentary pectorals occurring on the Atlantic coasts of the West Indies and South America. In the Indian Ocean, according to Dr. Günther, there is one species, *Solea Indica*, from Madras, also belonging to the subgenus *Achirus*. In the East Indian seas there are several species known: *Solea heterorhina*, from Celebes and Amboyna, and *Solea humilis*, from the Malacca Straits and Java, with well developed pectorals; *Solea trichodactylus* and *S. Thepassii*, with rudimentary pectorals. *Solea microcephala* lives on the coast of New South Wales in Australia; further north on the west side of the Pacific we have *S. Japonica*, from Japan, *S. ovata*, from Chinese seas. On the east side of the Pacific, on the coast of Central America, there are *Solea scutum*, *S. Fonsecensis* and *S. fimbriata*. Thus the genus is well represented in all the tropical seas, extending into the temperate zones both to the north and south. But no species is of any importance as human food except the *Solea vulgaris* of Europe.

CHAPTER II.

HABITS, FOOD, ETC.

The habits of the adult sole in its natural state cannot be directly observed: we can only ascertain the means by which it is captured, the character of the sea-bottom whence it is taken, the animals which are taken with it, and the food which is found in its stomach. By supplementing the knowledge thus gained with observations on the living fish kept in large aquarium tanks we can obtain a tolerably complete knowledge of the sole's mode of life.

The sole is rarely, if ever, captured by any other instrument than the trawl. The great majority of the soles brought to market are obtained by the large beam trawl, worked by the large deep-sea trawlers, but it is also frequently captured by the otter-trawl used chiefly by amateurs, and also by the small trawls used for catching shrimps and prawns. The usual depth at which soles are found is from 20 to 40 fathoms, but it may exist at greater depths; it probably does not extend beyond 100 fathoms.

Adult soles may occur at any depth less than 20 fathoms, but usually in shallow water, less than ten fathoms deep, only young individuals are found. However, exceptions to this rule occur not infrequently; the fisherman of the Plymouth Laboratory has several times caught an adult sole in Plymouth Sound within the Breakwater. Once he caught a full-grown specimen of large size in the Catwater, which is the estuary of the River Plym, opening into the north-east corner of the Sound. On May 9, 1889, he took a specimen $13\frac{3}{4}$ in. (35 cm.) long, a short distance from the mouth of the same estuary, and a third specimen he captured a little later in another part of the Sound. Small specimens six and a half to nine and a half inches (17 to 23 cm.) in length are not uncommon in the Sound, half a dozen being frequently taken in two or three hours' work with the shrimp trawl. These immature soles in fact, according to my experience, are more abundant within the Sound than on the neighbouring open shores outside it.

Off Plymouth soles are comparatively scarce at the present time: it is rare to take more than four or five in a single haul of the trawl, and sometimes only one or none at all are obtained. At a considerable distance south of the Eddystone they become

somewhat more plentiful. They are much more abundant on a rough area of ground to the west of the Eddystone, off Dodman Point in Cornwall. In this neighbourhood I saw about fifteen soles in a single haul of the trawl in April, 1889. This ground is often called the "California" ground, a name which was given to it when it was first worked at the time of the rush to the gold-diggings in California. On the area called by the Plymouth fishermen the Mount's Bay ground, soles are fairly abundant. This ground lies off the entrance of Mount's Bay to the south of the Wolf Rock. When I was on a trawler working there in April, 1889, the catches of soles numbered six, seventeen, and fifty-seven, in three different hauls. The species is still more abundant on the fishing grounds off the north coast of Cornwall, and in 1889 large numbers of trawlers from Lowestoft, Grimsby, and other ports on the east coast worked over these grounds for several months in the earlier part of the year; but I have never been there myself. In 1889 the Newlyn fishermen, who are usually exclusively engaged in drift-net fishing, found that large soles were abundant inside Mount's Bay on the west of the Land's End promontory. They obtained small trawls about twenty feet long which they worked over this area from their small luggers in the month of March, when no mackerel or other surface fish were to be caught. One boat in which I went out obtained eleven, seventeen, and eleven soles in three separate hauls, many of the fish being very fine specimens.

None of the grounds mentioned are at a much greater depth than forty fathoms; over the ground last mentioned the ground varies from twenty to thirty-five fathoms. All these areas are more or less sandy, the sand being in all cases of a very fine texture and of dull grey colour. Trawls cannot be worked over a hard and rugged bottom formed of rocks, but some of the grounds above mentioned where trawling is carried on are by no means smooth. From the California ground the trawl brings up numbers of the large mussel-like bivalve, *Pinna nobilis*, called caperlonga at Plymouth, numbers of Pectens, called at Plymouth queens, at other places scallops or clams, and large rugged stones. But we may conclude from the habits of the sole in the aquarium that such ground contains patches of loose sand or gravel, and that the soles live on these; for in the aquarium the sole invariably when alarmed, like all other flat-fish, buries itself in sand or gravel by rapidly shaking its longitudinal fins. If a live sole in captivity is placed in sea water on a smooth solid surface, such as the bottom of a flat porcelain dish, or the bare wooden or slate bottom of a tub or tank it instinctively shakes its fin in the peculiar way by which it shakes the sand or gravel over its "back," when there is any sand or gravel beneath it. This rapid movement of the fins is therefore a characteristic of its habits of life, and it is extremely effective. The fish on a layer of sand, when alarmed, disappears in an instant, the agitation of the sand renders the water around it turbid so that it is difficult to locate the exact spot where the fish has buried itself. Usually when resting undisturbed beneath the sand or gravel it leaves its eyes uncovered, and these can be detected by careful search: but not easily for they do not differ greatly in appearance from small

bright pebbles or fragments of stone. When the material the fish rests on is fine, like sand, or contains an admixture of fine particles, a thin layer of the finer material remains on the back of the fish when it emerges and moves about; the fine particle are retained on the skin partly by the adhesive property of the viscid mucus which exists on the skin of all fishes, and partly by the minute spines of the scales. The sole thus moving gently about with its upper side covered with sand is partially concealed, often only its actual movement betrays its existence.

Solea lascaris is a rare fish in the neighbourhood of Plymouth. For a long time I never met with a single specimen. The fishermen did not seem to know it by any of the vernacular names given in books. The first specimen I obtained was discovered by the Laboratory fisherman among a number of common soles exposed on the fish quay for auction. He selected it on account of its peculiar appearance, after I had described the species to him and requested him to search for specimens. The fisherman to whom it belonged when asked its name said it was a "sand-sole." I could not ascertain accurately where this specimen was taken, but it probably was caught a long distance from land towards the central region of the channel. On June 17, 1889, I trawled at night in Whitsand Bay for the purpose of obtaining if possible young specimens of the common sole. In the products of this trawling I discovered on my return three small specimens of *Solea lascaris* measuring $7\frac{1}{2}$, $7\frac{1}{2}$, $6\frac{3}{4}$ inches (19 cm., 19 cm., 17 cm.), respectively. The depth of water where these were taken was three to five fathoms, the bottom a fine clean sand of light yellow, almost silvery, colour.

Solea variegata, the thickback, is very common off Plymouth, but only in deep water. I have never met with a specimen in or near the Sound, either young or adult. On April 19, 1889, when I was on board a trawler fifteen or sixteen miles S.W. of the Eddystone, 213 thickbacks were taken in a single haul of the trawl. On the Mount's Bay ground they are much less plentiful.

Half-grown specimens of *Solea lutea* are fairly common in Plymouth Sound, but I have never found adults there. The only adults I have seen were obtained from deep water by a larger trawl, and the exact locality was not recorded. In the Sound the young specimens, one to two inches in length, are especially abundant in Cawsand Bay, in three to five fathoms of water on a bottom of fine sand of a dull grey colour. I have frequently taken half a dozen there in a single haul of the shrimp trawl, together with young scald-backs (*Arnoglossus laterna*). The shrimp trawlers believe both these fish to be the young of the common sole.

I have not been able to keep thickbacks alive in the aquarium, but there are living specimens of the *lascaris* and *lutea* in our tanks, and they do not differ in their habits from the common sole.

There is no doubt, then, that the common sole lives naturally on ground consisting of sand or gravel or other loose material, and that it has the instinct of seeking concealment by burying itself beneath the surface of the ground by a rapid shaking of

its fins, an instinct which is exercised at the least cause of alarm, as the fish is exceedingly shy and timid. All the other flat-fishes have the same habit, but of those observed in our aquaria, namely, the plaice, dab, flounder, and turbot, none remain concealed so persistently as the sole, at least in the daytime. In the night soles behave quite differently, they then emerge from beneath the ground and move actively about in search of food. In the daytime it is extremely difficult to discover how many soles there are in a given tank even by driving them out of the gravel with a stick: but on going to the same tank in the dark with a lighted taper one may count twenty or thirty where only five or six were expected. But they soon disappear if the light is held over the surface of the water.

The sole then is a nocturnal fish in the aquarium, and therefore doubtless also at the bottom of the sea. This agrees with the belief of the majority of trawlermen that more soles are caught in the trawl by night than by day. I have met one or two fishermen who deny this and assert that they have sometimes taken a good number of soles in a daylight haul and scarcely any in the following night. But of course exceptional cases may well occur, and are probably to be explained by the fact that soles were abundant in the track passed over by the trawl in the daytime, and very scarce in the ground swept at night. Of course some soles are taken in daylight, and it will be easily understood when the mode in which the trawl works is considered, that it depends on the position and behaviour of each individual sole whether it passes over the foot-rope into the net or not. If the foot-rope is heavy and the trawl going at a moderate speed it may disturb the ground deep enough to cause most of the soles in its path to rise from the bottom, in which case they will most likely pass over the foot-rope and be swept into the net: if on the other hand the foot-rope passes more lightly over the surface, or if the soles bury themselves more deeply instead of rising in alarm the rope will pass above them and they will escape capture.

There can be no doubt that at 30 to 40 fathoms depth beneath the surface of the sea there is in the daytime a good deal of light, but still much less than at the surface or in an aquarium tank. It has been ascertained that light disappears altogether at 200 fathoms, and if we assume that the absorption is proportional to the depth there must be at 50 fathoms three-quarters of the quantity of light that exists at the surface. Now the quantity of light in our aquarium is a great deal less than the quantity outside, as a great part of the windows are obscured. It follows, therefore, that the tanks in the aquarium are not very much more illuminated than the sea bottom at a depth of thirty fathoms, and it may justly be concluded that soles in their natural condition at that depth will for the most part remain buried during the day and emerge from the sand to seek food at night: the sole therefore is a nocturnal fish in its natural state.

The Food of the Sole, and its Method of Feeding.

Although the sole is more active by night than by day, it can often be seen feeding in our tanks in the daytime: there is not a constant supply of food in the tanks, and when food is thrown in the fishes are usually so hungry that they begin to feed at once. The food supplied to the soles and other flat-fishes consists principally of marine worms (chiefly *Nereis Dumerilii*), shrimps, and fish cut up into small pieces, usually pilchard, mackerel, or gurnard. Of these the soles prefer the worms. In seeking their food the soles are guided first of all by the sense of smell: by this they perceive the presence of food in their neighbourhood, and the sense of sight is not employed for this purpose. But in hunting for their food, and in localising its position before biting at it, they rely entirely on the specialised tactile filaments of the skin on the under side of the head. A sole when searching for food moves slowly about gently tapping every part of the sandy bottom with the lower surface of its head. While the sole is thus engaged its back is very frequently covered with a thin layer of sand, so that scarcely any part of it is visible except the eyes and mouth and some of the filaments below the snout when the latter is raised: it is only noticeable on account of its movements, and because its form can be traced out and distinguished from the flat surface of the sand around it. When in the course of this deliberate exploration the lower side of the head feels a worm or other morsel of food, the sole immediately seizes it with a vigorous and sudden snap of the lower half of the jaws where the teeth are situated, and then swallows it with the sand which adheres to it. I have often placed a worm on the upper side of a sole thus engaged in hunting its prey. When this is done it makes not the slightest difference to the sole's behaviour: the fish goes on tapping as before, evidently unconscious that it is carrying a palatable morsel about with it. When the sole feels a worm or other piece of food with its tactile filaments it cannot see it, and it never snaps at any food which it has not first felt in this way. It is in fact unable to localise the position of its food and so to direct the motion of its jaws to the object to be seized unless it has felt this object with these tactile filaments. In other words the afferent sensory impulse produced by the contact of the food with the sensitive filaments is necessary for the co-ordination of the movements of the head and jaws by which the food is seized.

I have examined the intestines of a large number of soles in order to discover what they had been feeding on before they were caught. It is the custom of trawlers to gut their soles on board before they put them away in the hold of the vessel. They also gut turbot, brill, dorey, and haddock, though of the latter they do not usually catch many off Plymouth; sometimes they take a considerable number off Mount's Bay and the north coast of Cornwall. I obtained the intestines of soles sometimes by putting them into a jar of spirit when I was out with a trawler myself, more frequently by sending jars of spirit on board a boat and paying the men to bring back in them the

intestines of all the soles they caught. It is very seldom that anything is found in the stomach or intestine of a sole which can be satisfactorily identified. The stomach is very slightly differentiated, it is only distinguished by the somewhat greater thickness of its walls from the intestine, and is only marked off from the latter by a slight pyloric constriction situated beneath the middle of the liver. The stomach after death is almost invariably found empty. In the course of the intestine in a small percentage of specimens small masses of the indigestible remnants of food occur. These masses are usually black and enveloped in mucus. Usually they contain fragments of shells with bristles of marine (Chætopod) worms and other *débris*, and rarely something is found in them whose specific origin can be recognised. The following is the record of the intestines I have examined:—

December 22 and 23, 1887, 9 miles W. by S. of Eddystone, 40 fms. A number of specimens: six contained food.

(1.) Proboscis of Gasteropod, one small Ophiurid, pieces of Lamellibranch shells.
(2.) Pieces of Lamellibranch shells, and remains of the contained animals.
(3.) Fragments of Lamellibranch shells.
(4.) Ditto.
(5.) Ditto, and a long specimen of errant Polychæte worm, genus and species unrecognizable.
(6.) Fragments of Lamellibranch shells.

January 23, 1888. Nine miles S.W. of Eddystone, nine specimens, two containing food.

(1.) *Nika edulis*, Risso (a Decapod Crustacean) a single specimen; also a Holothurian, sp.?
(2.) Remains of Chætopoda.

Same date. Six miles S. of Eddystone, sixteen specimens, all empty except one.

(1.) A piece of *Sertularella* (Hydroid).

January 30, 1888. Nine miles S.E. of Eddystone; bottom sand. Fourteen specimens, three containing food:—

(1.) Two *Synapta digitata.*
(2.) Several *Ophioglypha albida.*
(3.) Two *Ophioglypha albida.*

February 7, 1888. Seven or eight miles W. by S. of Eddystone; "queen ground," *i.e.*, *Pecten opercularis* abundant on the bottom; nine specimens, four containing food.

(1.) Nine *Ophioglypha albida*; one Chætopod unrecognizable.
(2.) One Chætopod.
(3.) Two *Ophioglypha albida*, one Amphipod.
(4.) Four *Ophioglypha albida*, one Amphipod.

February 17, 1888. Twenty-five miles off the Lizard, 40 fms., sand. A great number of specimens, eight containing food.

(1.) Remains of *Ophioglypha albida*, and fragments of Lamellibranch shells.
(2.) Fragments of Lamellibranch shells.
(3.) A few fragments of shells, small pieces of membrane, and a large number of large Chætopod bristles, *Aphrodite* or *Hermione*.
(4.) Small Lamellibranch shells and fragments. One of these close to the anus was entire, the colour unaltered and the animal undigested.
(5.) Small Lamellibranch shells and bristles of *Aphrodite* or *Hermione*.
(6.) Fragments of shells; one small Lamellibranch Donax shell entire near anus, animal absent.
(7.) Chætopod bristles.

March 24. Off Mount's Bay. Thirty-seven specimens, ten containing food.

(1.) Pieces of Sertularian Hydroid, and remains of Chætopod tube.
(2.) Anterior part of large Chætopod of fam. Terebellidæ. Fragments of shells. Piece of *Cellaria fistulosa*.
(3.) Fragments of shells. Piece of Chætopod tube.
(4.) Large Chætopod bristles, probably of *Hermione*.
(5.) Piece of Chætopod tube. Fragments of shells
(6.) Large bristles, probably of *Hermione*.
(7.) Piece of Chætopod tube. Fragments of shells.
(8.) Fragments of shells.
(9.) Large bristles, probably of *Hermione*.
(10.) Tail of Decapod Crustacean, probably shrimp.

April, 1889. Off Mount's Bay. A large number of specimens.

(1.) Bristles of Chætopoda.
(2.) Bristles of Chætopoda, among them the dorsal hook of *Melinna cristata*, Malmgren.
(3.) Cuticle of a long specimen of *Lumbrinereis sp.*
(4.) A long, much-digested specimen of a Gephyrean, *Sipunculus* (?)

Also in several the aciculi of *Hermione* or *Aphrodite* and, in several, cylindrical masses of *débris* containing small shells, *e.g.*, *Pecten tigrinus* and fragments of shells, entangled fibres, and pieces of membrane from the tubes of tubicolous Chætopoda; also fragment of calcareous Polyzoon.

I believe that the fragments of shells and pieces of tough membrane which occur so frequently in the sole's intestines are the remains of the tubes of *Thelepus circinnata*, Malmgren, a Chætopod belonging to the family Terebellidæ, which inhabits a membranous tube attached by its whole length to stones or shells, and covered externally with calcareous fragments of all kinds, such as fragments of shells, or entire small

shells, small stones, pieces of calcareous Polyzoa, &c. If this is so, this species and others possessing a similar tube must form a large portion of the sole's food. The total number of specimens the contents of whose stomachs are recorded in the above list is thirty-six. Of these eighteen, or 50 per cent., contained remains of marine annelids (Chætopods). If we add to these the number of specimens which contained no remains of Chætopods but fragments of shells, probably derived from the tubes of annelids, the number becomes twenty-eight or 77 per cent. Seven specimens contained *Ophioglypha albida* or other Ophiurid, or 19 per cent. One specimen contained *Synapta digitata*, and one another Holothurian. Crustacea were present in four specimens, or 11 per cent. In three specimens there were Mollusca probably not derived from the tubes of Chætopods, or over 8 per cent. Thus it is evident that soles in their natural state feed chiefly on Chætopods, and it is probable that the bodies of these are rapidly digested, so that it is very difficult to identify the species to which their remains belonged.

Parasites.

The common sole is remarkably free from parasites, which in many fishes occur constantly in great number and variety. I have seen no internal parasites in the sole except an occasional Nematode, or small thread-worm. Of external parasites the only form I have observed is the Trematode, *Phyllonella soleæ*, whose structure has been described at length in the preceding Section. This creature appears to do no harm to the fish. I have never seen any signs of irritation or inflammation of the skin on which numbers of the parasite were living. Sometimes as many as twenty or thirty specimens of the parasite occur on a single sole. *Phyllonella* is, as I have described it previously, hermaphrodite, but it does not fertilise its own eggs. I have not seen it in copulation, but it may be inferred from the structure of the generative organs that two individuals copulate reciprocally, the penis of each being inserted into the uterus of the other, and the seminal fluid received by each uterus passing up the oviduct to be stored up in the spermathecæ. Fertilisation of the ova then takes place after copulation, and is effected by the spermatozoa which are expelled from the spermathecæ into the vestibule into which the ova pass from the ovary. The fertilised ovum, together with a quantity of yolk, is surrounded by its peculiar shell in the uterus and then the deposited ovum adheres by its filament to the skin of the sole. I have not traced the development of the parasite, but have no doubt that it is direct, that the young is hatched in a form closely resembling the adult, and immediately adheres by its posterior sucker to the sole's skin. The parasite doubtless is nourished by the mucus of the skin on which it lives, but how far its nutrition is effected by digestion of the mucus within the small alimentary sac, and how far by direct absorption through the surface of the body, it is impossible to say. The parasites spread from one sole to another in all probability when the fish accidentally come into contact with one another.

Enemies.

I am inclined to think that the principal and most deadly enemy of the sole is man. But my evidence on this subject is by no means extensive. I have never seen an adult sole in the stomach of any fish except the angler, but on the other hand, I have not devoted much time to recording the contents of the stomachs of the larger predatory fishes. Considering the great timidity of the sole it is difficult to avoid the inference that it has many enemies to fear. Probably young soles and other flat-fishes living in the conditions in which I found them in Mevagissey harbour are largely devoured by gulls and shore birds when left by the receding tide in the shallow pools of the shore, but I cannot assert this from direct observation. I have once or twice seen large conger seize and devour flounders in a large tank of our aquarium; there were no soles in the same tank, but it may be inferred that conger would devour soles when they had the opportunity, and that they do devour them in the open sea. But it must be mentioned that our captive conger have by no means eaten all the flounders in their tank; probably they are never so hungry when fed regularly in captivity as when they have to seek their own living in the wild state, and therefore conger may reasonably be reckoned, on the south coast, among the enemies of the sole. I have never seen the common spotted dog-fish (*Scyllium canicula* and *Sc. catulus*) eat flat-fishes in the tanks, though they are kept together in the same tank, but I think cod and hake probably eat soles and other flat-fishes sometimes. One of the commonest and most destructive enemies of ground fishes is the angler (*Lophius piscatorius*) which grows to an enormous size and consists almost entirely of a huge mouth and a small conical tail. I have frequently seen several large specimens of this fish in a single haul of the trawl, and it constantly swallows other fish, including flat-fish, even after it is in the trawl, its voracity being so great that it devours its fellow captives. I have often seen soles taken from its stomach on the deck of a trawler, and when extracted they are usually quite uninjured and are packed away with the rest for market; so that when we eat a sole we cannot be certain that it has not been swallowed before. The angler is very inactive, its powers of locomotion being limited. It partly buries itself in the sand on which it lives, and its colour and appendages are such that in this condition its true character is perfectly concealed. Over the head are long flexible filaments which are supposed to serve as a lure to attract other fishes, but which probably have little effect on soles because they do not hunt by sight. The angler thus forms a living and deadly pitfall. Any fish coming unconsciously near its terrible gape is seized and engulphed in the great cavity of its mouth, and soles of the largest size are swallowed by it with ease.

CHAPTER III.

COLOUR.

The colour and markings of the upper side of the common sole, so far as they are permanent and characteristic of the species, have already been described. But, as was mentioned in connection with that description, the skin of the fish is capable during life of exhibiting considerable changes in the intensity and to some extent in the quality of its colours. It is exceedingly difficult to study these changes of colour in a living fish if the material on which it is placed consists of fine particles, like sand or mud. For the fish will persist in burying itself, and it is impossible to keep the skin free from particles of the material, so that an accurate estimation of the colour under particular conditions can scarcely be made. It is not difficult to keep a sole alive and in a healthy condition for several days or even weeks in a shallow vessel supplied with a current of sea water. In order to study the colour-changes carefully I kept specimens in this way, allowing them to rest either on a solid surface or on a material of coarse texture without fine particles, namely, coarse gravel or broken coal thoroughly washed in running water.

It is generally believed that the colour and marking of the sole's skin assimilates itself to the colour and texture of the ground on which it rests. The following observations were made in order to obtain definite results as to the extent and character of this assimilation: I found that the contrast between the markings and the ground-colour of the skin was most conspicuous when the fish was lying on a coarse bright clean gravel. The gravel which I used had a general orange tint, but it contained, besides yellow and orange coloured pebbles, a considerable number of black and white. The appearance of the fish when resting on this gravel is shown in Plate I. The ground colour is a greenish grey, and on this ground all the spots and markings ever present in a sole are well marked. The principal dark blotches are very conspicuous and well defined; the irregular lighter bands which connect them ramify in the spaces between them. The blotches are in places quite black, the black being always confined to the outer part of the scales, the anterior part of these being always somewhat lighter. The small white spots alternating with the blotches are also fully expressed. The dark spot at the outer end of the pectoral is pronounced. It is evident from the drawing that there is no exact similarity between the colour and markings of the fish and the appearance of the surrounding gravel; but it is also

evident that the sole in this condition has, like the gravel, a variegated colouring which at some distance from the eye renders it less conspicuous. The black spots and the small white spots resemble the black and white pebbles of the gravel; but on the other hand, the continuous streak of opaque white along the edge of the fins is distinctly conspicuous. A sole on gravel of this kind in a tank of some size is usually either completely or partially buried under the gravel, and when the fins are thus concealed and only part of the body exposed the sole may easily escape notice from a human observer. On the other hand, it is also very easy to discover a sole in such a condition when one looks for it. I believe that soles are seldom on gravel in their natural state; for I have found that on gravel or sharp sand they nearly always sooner or later injure their fins or skin, and that abrasions so produced usually lead to inflammation which causes death.

I placed another sole in a large shallow dish of white porcelain of the kind used in photographic manipulation. No material of any kind was placed in the dish, the fish rested on the smooth white surface of the porcelain, and it was exposed to the full daylight of the south windows of the Laboratory. Plate III is a reproduction of the water colour drawing made from the sole in this condition. The paleness of the colouring is extraordinary. The darkest tint in the blotches is a straw colour, scarcely darker than the yellow of the fin-membranes. The ground-colour is a pale grey with a slight tinge of blue in places. The white spots have disappeared entirely, a result which would not have been expected: the spots where they existed are somewhat blue. The dark spot on the fin is the darkest colour in the whole surface, and has still streaks of dark brown between the fin rays. The sole used in this experiment was a male $10\frac{1}{2}$ inches (26·7 cm.) long; but I found that the sole from which Plate I was drawn became as pale as this when placed under the same conditions.

The drawing of the sole just described was finished on June 8, 1889. This sole died shortly afterwards and its appearance the day after death is represented on Pl. IV. Another sole was taken for the drawing given in Pl. I. I found when this latter specimen was placed on the white porcelain that it became in a few minutes as light as the figure on Pl. III, but after it had been left all night in the same condition, on the following morning the small spots which on gravel were opaque white had become quite a dark grey and formed a marked contrast to the surrounding yellow.

To ascertain the maximum darkening of colour possible I used the same sole from which Pl. I was taken. At first I found it difficult to produce any colouring much darker than that of Pl. I. I lined the porcelain dish with black paper and placed the fish on that, but it showed much the same colours. Then I varnished the dish with black varnish of a deeper black than the paper, but got no better result. It then occurred to me that the maximum of darkness could not be obtained until the quantity of light was reduced; accordingly I placed some washed coal at the bottom of a tub about nine inches deep, and placed the sole on this; then I placed the tub on the

north side of the Laboratory at some distance from the windows in a position where it was partly shaded. Then the result shown in Plate II was produced. But the drawing for this plate had to be finished from the sole in the position I have described. When the sole in the tub at its maximum darkness was carried to a table in front of the window, the colours immediately began to get lighter. I found that the white spots were exceedingly curious in their behaviour. As I have mentioned, on white porcelain with plenty of light the white spots disappear as such and are changed into bluish spots which sometimes become quite dark and conspicuous. The white spots also disappeared in the sole which was kept on coal with very little light, reappearing in a few seconds when more light was admitted. Thus the white spots are generally visible except on white ground with a great deal of light, or black ground with very little.

As to the rate of change it is usually quite rapid. A sole placed on the white dish begins to get lighter almost immediately; when it is disturbed with the hand the colours become darker again, but when left alone it continues to grow paler. However, the full effect is not seen till the fish has been some hours on the white ground.

A sole kept on coarse yellow gravel in front of a window is very inconstant in its colouring: it sometimes exhibits its markings quite distinctly for some hours, and then begins to grow pale, its black blotches almost vanishing.

On May 22, I took a sole in which the markings were well expressed and the colour moderately dark, and placed it on the white porcelain dish; in a short time the colours had become pale, and the dark blotches had become yellow. Then I placed some fine shingle in the dish, intending to bring the markings out again, but to my surprise the black blotches had not returned when I examined the fish the next morning, and did not return completely when I placed it in an oaken tub nine inches high, although the ground colour became somewhat darker.

All the changes are evidently due to the action of light and depend on the quantity of light acting on the sole, not on the tint or texture of the ground on which it rests. The behaviour of the white spots I cannot yet explain, but all the rest seems to me easily intelligible when regarded in this way. The colour and markings of the skin are due to a vast number of chromatophores situated in the skin beneath the epidermis: these are of two colours, the black and the yellow, and in some places there are others containing a somewhat iridescent pigment. The last are particularly abundant in the white spots, the black especially abundant in the dark markings. Light causes these chromatophores to contract. When expanded the chromatophores or pigment-cells are stellate, giving out ramified processes on all sides. When they are contracted all these processes are withdrawn and each cell becomes a mere minute speck of pigment. The position of these chromatophores is fixed, and therefore when they are expanded, in the absence of light, the markings always reappear in exactly the same positions, in fact the markings never entirely disappear. When a very strong light falls upon the sole all the chromatophores are contracted, and all the parts become proportionally

lighter; when the light is diminished the chromatophores expand and the colours become darker. It is evident that with the same amount of illumination the alteration of the colour and composition of the ground on which the sole rests alters the quantity of light acting on the fish. For if the ground is black all the light which falls upon that ground is absorbed, and the sole is only affected by the rays which fall directly upon it, while if the ground is light-coloured nearly all the light which falls upon it is reflected, and the diffused light which falls upon the sole is therefore greatly increased. Just as a room is much lighter with the same windows if its walls are white than if they are black.

The sole does not become uniformly coloured on a uniformly coloured ground. In some of the laboratory tanks we have at the bottom a dark grey fine sand brought from a part of the sea shore. This sand is extremely uniform in colour, and is exactly of the same kind as the sand brought up by the trawl from the trawling grounds off Plymouth and off Mount's Bay. In the tanks the soles usually have some of this sand on their skins, and are therefore by no means conspicuous, but whenever their skins are visible it is seen that the black markings are pronounced. The ground colour of the soles in this condition approximates closely to that of the sand, but the presence of the black spots does not seem to me to aid in the resemblance at all. I placed a large sole in a shallow tub on some of this sand in order to make a careful observation. After three days the colouring of this sole was as follows: The intermediate black spots were almost invisible; of the dorsal series the second was faint, the third, fourth, and fifth well marked and black; of the median series only the third and fourth were well marked, but not black. The ventral spots were all visible but faint; termination of the pectoral reddish-brown, white spots alternating with black quite distinct.

CHAPTER IV.

BREEDING.

The egg of any particular species of fish is derived from a female individual of that species, and after a process of development becomes another individual of that species, presenting the characteristic specific characters. As the eggs of nearly all marine fishes are left to themselves after being shed from the body of the female, the parents taking no care of them, there are only two possible methods of ascertaining the species to which a particular kind of egg belongs, or of tracing the development of any particular species of fish. One method is to observe the deposition of the eggs by the female, or to detain them by artificial fertilisation, then to examine these eggs and study their development. The other is to examine all kinds of eggs that can be obtained, and to trace their development up to the stage when the young fish presents specific characters by which it can be identified. The latter method presents more difficulties and uncertainties than the former.

The greater number of marine fishes shed eggs or spawn at one particular period of the year, a period extending over one or a few months. During the rest of the year the development of ova in the ovaries proceeds gradually until the next annual breeding season, when the annual crop of mature ova is again shed. As the ova develop in the ovary they increase greatly in size and number, and thus the ovary itself becomes much enlarged, and finally attains a very considerable size in proportion to the rest of the body of the female. This enlargement of the ovary produces a corresponding enlargement of the visceral region of the female. The small testes do not exhibit any corresponding increase in size in the sole. In most fishes the testes in the male enlarge at the breeding season in some degree, and in some they become very nearly as large as the ovaries in the female. In the herring, for instance, it is not possible to distinguish the males from the females among ripe specimens taken from the net when captured, except by squeezing them and observing whether eggs or milt escape from the genital aperture. But in the sole the ripe females can be easily distinguished by the enlargement of the ovarian region. It is not so easy to distinguish the smaller males from small immature females, but among larger specimens the males can usually be identified by holding the fish up against the light, when in the male the posterior part of the ventral region behind the intestines is seen to be translucent; while in the female even

if the ovary be not much enlarged it usually produces an opacity extending back far behind the intestines near to the base of the tail.

The enlargement of the ovaries in the female sole becomes noticeable in January and February, and ripe actively moving spermatozoa are found at this season by examining under the microscope a portion of the testis of the male. I have not succeeded in observing the natural deposition of the ova by living soles in captivity. I attempted to do this in the spring of the present year (1889). At my request living soles were brought to the aquarium during the previous winter months from the deep sea trawlers and from the shrimp trawls worked in Plymouth Sound. But the specimens obtained from the latter were all small, and although they lived well were too young to breed; while the larger ones from the large trawlers although living when brought in invariably died after a few days in the tanks. The reason of this was that the large soles were always more or less injured by the trawl or by subsequent handling. The large trawls are towed usually for a long time, six to twelve hours or more, and the captured soles and other fish during this time are injured by their struggles and by the pressure and weight of the whole contents of the trawl. After the soles are placed in tubs of water on board the vessel the voyage back to harbour occupies a long time during which they are knocked about by the motion of the vessel. In consequence of this mechanical violence the skins of soles brought to me from the deep sea were always more or less abraded, and the scales torn off at one or more places. The injured parts of the skin in a few days always underwent inflammation and sloughing, and the diseased condition spread over the surface till the fish died. I have found that the sole is tenacious of life and will bear a great deal of handling so long as the skin is uninjured and the scales not removed, but that very slight injury to the skin and scales leads to inflammation and death. In other fish, for instance, the conger and grey mullet (*Mugil chelo*), considerable wounds on the skin are healed up in a very short time without any inflammation; the mullet will reproduce nearly all its scales in a week or two.

I was unable therefore to study the breeding of the sole in specimens living in captivity, and my investigations of the reproduction of this species, as of many others, have been carried on at sea on board of trawling smacks by examination of the fish when brought up by the trawl.

With very few exceptions the eggs of all deep sea food-fishes have been found to be small in size, spherical in shape, transparent, and buoyant in sea water, and after being extruded by the parent fish to undergo development while suspended, separate and independent of one another, in the surface waters of the sea. All the flat-fishes investigated have been found to shed eggs of this kind, and the sole proves to agree in this respect with its allies, the plaice, flounder, turbot, &c. As in other fishes, gentle pressure by the fingers and thumb applied to the ovarian region of the ripe female sole causes the ripe ova to escape from the aperture by which the ovaries open to the exterior. The ovaries lie entirely behind the aperture, and therefore the pressure must

be exerted from behind forwards. To examine the eggs and keep them alive they must be received when pressed from the fish into a bottle of clean sea water. By squeezing a number of captured soles in this way in March, when the ovaries are found to be much enlarged and soft to the touch, some are found from which transparent eggs can be pressed out. When a considerable pressure is exerted part of the contents of the ovary can be squeezed out of any sole in which the ovaries are large, but when the ripe transparent ova have once been obtained it is easy to distinguish them from the smaller unripe ova which escape when too much pressure is applied. These unripe ova are yellowish-white and quite opaque: they do not separate from one another when they fall into sea water, and membranes containing blood, derived from the tissues of the ovary, are usually seen connected with them. In March a number of soles taken at one haul of the trawl include, besides somewhat small immature specimens and males, some large females which yield no ripe eggs, whose eggs have not yet reached maturity, and only one or two from which ripe eggs can be obtained. Very often only a small number of ripe eggs can be obtained when the fish is first squeezed, afterwards unripe eggs escaping. This proves that the eggs in the ovary are not matured all at once, but in gradual succession. But the process of ripening seems to become more rapid towards the end of the spawning period in a given fish than at the beginning, and the eggs are evidently extruded immediately after they are ripe; for although I have examined large numbers of female soles which yielded a few dozen ripe ova, and whose ovaries after the extrusion of these remained distended with unripe ova, I have only once found a specimen whose ovaries contained ripe ova only. This specimen was captured in a small-sized trawl worked from a Newlyn drift-net boat, on the morning of March 23, 1889. I squeezed several thousand ripe ova from it, and the ovaries were then completely empty. When all the ova of one season are shed the ovaries are left as flaccid sacs which soon shrink considerably in size. Fish in this condition are usually said to be "spent" or "shotten": the latter is the Scottish expression. The specimen just referred to was of very large size. It measured 20½ inches in length, 9½ in breadth. The boat by which it was taken was trawling at a depth of about 30 fathoms on the north-west side of Mount's Bay, off the coast of the Land's End promontory. At the same haul, and in others previously made, shotten females, partially ripe and unripe females were taken. The only conclusion to be drawn from these facts is that only a few ova are ripened at a time in a given female at the earlier stages of the spawning process; while at the later stages though a large number of ova are ripened at one time they are very soon shed, and therefore the capture of a female at the particular moment when she contains a large number of ripe ova is a rare occurrence.

As stated above the spent condition of the female is easily recognised, and when only spent females are captured the end of the spawning period for the species is determined. I investigated the duration of the period during the two successive seasons of 1888 and 1889, and found that it ended some weeks earlier in the latter year than in the former, a fact which can only be explained by the warmer weather

and consequently higher temperature of the sea in the spring of 1889. In the latter year, when on board a trawler south of the Wolf Rock which lies to the west of the Land's End, on April 11 and 12 I found nearly all the female soles completely spent, a few containing nothing but a small number of ripe ova. The surface temperature of the sea at that time and place was 48°·5 F. (9°·2 C.). In 1888 the fisherman in the service of the Plymouth Laboratory obtained ripe soles on April 26 and 27 at a distance of 40 miles north of the Land's End where the surface temperature was 46°·0 F. (7°·7 C.) and the bottom temperature at 50 fms. was 45°·0 F. (7°·2 C.). The temperature on April 6, 1888, to the south of the Wolf Rock was 46°·0 F. (7°·7 C.). The following temperatures of the surface of the sea will show the difference of the two seasons:—

1888.				1889.			
		F.	C.			F.	C.
March 6.	S. of Wolf Rock	45°·8	7°·6	March 1.	S. of Wolf Rock	48°·0	8°·8
April 4.	„ „	45°·5	7°·5	April 9.	„ „	48°·5	9°·2
May 10.	„ „	50°·1	10°·0				
March 26.	S. of Plymouth Breakwater	43°·0	6°·1	April 3.	S. of Plymouth Breakwater	46°·0	7°·7
„ 29.	„ „ „	43°·5	6°·3	May 15.	„ „ „	54°·0	12°·2
April 9.	Plymouth Sound	44°·0	6°·6	„ 21.	„ „ „	56°·5	13°·6
May 31.	S. of Plymouth Breakwater	49°·0	9°·4				

I have not determined so exactly the commencement of the spawning period in the two seasons. In 1888 I examined several soles taken nine or ten miles W. by S. of the Eddystone, on February 6. Only one yielded a few ripe ova, about a dozen; the rest were all unripe.

It is thus evident that the spawning period of the sole extends from the middle of February to the end of April; but that the greater number of individuals shed their spawn in March, and the early part of April; and that in warm seasons the spawning is completed by the end of the second week in April; while in colder seasons some individuals are found still spawning up till the end of April, and a few eggs may not be shed till the middle of May.

Little has yet been said about the males. Necessarily the male reproductive elements consisting of the fluid milt, which contains the innumerable spermatozoa, are discharged at the same period as the ova. But the testes and the milt of the sole differ remarkably from those of any other marine fish I have examined. In other fishes the testes in the spawning season are much enlarged, and very soft, so that when the fish is opened very slight handling tears or ruptures the testes, causing the escape of a thick viscous opaque white fluid, the milt. When the ripe male fish is gently squeezed the milt escapes from the genital aperture in large white drops having the appearance of milk, which when allowed to fall in sea water mix with it and render it turbid. But when a male sole is opened in the breeding season the testes

are neither much enlarged nor soft : they present much the same appearance as at any other time of the year, though spermatozoa may be seen in a portion examined under the microscope. And when the male is squeezed in the region of the testes, no milk-white fluid is seen to escape ; some fluid may, and does, escape, but it is small in quantity and thin and transparent, so that it is almost impossible when handling soles on board a trawler to distinguish milt thus squeezed out from the sea water, urinary fluid, or mucus from the skin, which also drip from the fish.

CHAPTER V

DEVELOPMENT AND GROWTH.

The eggs of fishes do not develop unless acted upon by the milt of the male. In all species of marine bony fishes, with very few exceptions, the eggs do not come into contact with the milt until after they have been discharged from the body of the female; the whole process of development takes place outside the body of the parent in the water of the sea. When the egg of a bird is laid it requires only to be kept at a certain constant temperature to develop into a chick. When the egg of a snake or lizard is laid it develops at the natural temperature of the air without any additional warmth derived from the mother's body, and after a certain time a young snake or lizard is hatched from it. When the egg, or "purse," of the skate is laid, or taken from the body of the mother, it develops into a young skate as it lies at the bottom of the sea, or in an aquarium tank. In the spiny dog-fish (*Acanthias vulgaris*), the eggs develop within the oviducts of the female, and do not escape till they have reached the condition of actively moving young dog-fish, in all respects except size resembling their parents. But in all these cases the egg has been acted upon by the milt of the male while still within the body of the female. When ripe eggs are pressed from the ovary of the female sole into clean sea water they do not develop into young fishes, but after floating for a few days in the condition previously described as that of the unfertilised ovum they die, sink to the bottom, and decompose. This proves that the eggs of the sole are not fertilised or acted upon by the male reproductive elements within the body of the mother, but only after extrusion.

I have not been able hitherto to observe the natural process of shedding and fertilising the eggs of the sole in living specimens in our tanks, and it is of course impossible to observe the process in living soles in the sea. It is known that in pelagic fish, like the herring, the fish spawn while collected in crowded shoals, males and females being mingled together, and that the females simply shed their eggs, and the males their milt into the water near the bottom simultaneously. The water into which the eggs pass is thus teeming with spermatozoa, and none of them can escape fertilisation. But in the herring the testes are as large as the ovaries, and the quantity of milt produced by a single fish is very large. In most flat-fishes

the testes are smaller than the ovaries, but still they are of considerable size, and a considerable quantity of milt is produced. When we consider the small size of the testes in the sole, and the small quantity of milt produced by a single male, it seems difficult to understand how the large number of eggs produced by a single female get fertilised at all. It seems to me that the only way to explain the facts is to suppose that soles pair together like birds, or at least that the males do not like some other fish shed their milt into the water at random, but shed it in the immediate neighbourhood of a female at the moment when she discharges some ova. Some of the wrasses pair and shed their milt in this way: I remember watching the process once in one of the tanks of the Naples aquarium, but I do not remember to what species the fish I saw belonged.

After I had drawn the inference that some kind of direct fertilisation took place in soles, I found my opinion supported in a curious way by a statement of Nordman in his description of the fishes of the Black Sea, published in 1840 (see Demidoff's "Voy. Russ. Merid. Zool., III, Poissons," *Solea nasuta*). The statement I refer to is that the male and female of the species called by Nordman *Solea nasuta*, which is, as far as I can see, the same as the *Solea lascaris* of the English coast, during copulation adhere together by means of a glutinous liquid, and are sometimes taken in the nets in this condition.

The ripe ova pressed from female soles during the spawning period, when placed in a bottle containing sea water taken from the surface of the sea at the place where the fish are caught, float at the surface of this water. That ova so obtained are perfectly ripe and uninjured by the artificial method by which they are taken from the fish is proved by the fact that when milt is added to the water the eggs are fertilised, and when taken on shore and kept in proper conditions will go on developing until they hatch into normal young fish. This is the process of artificial fertilisation which will be more fully considered in the next section. The observation of artificially fertilised ova kept in aquaria shows the rate at which the development proceeds at a given temperature, for it must be noted that the rate of development of all fishes' ova varies considerably according to the temperature of the water in which they are contained. The following are the details of my observations on artificially fertilised ova kept in aquaria:—

May 16, 1888.—Two or three soles' ova fertilised south of the Wolf Rock at 4 p.m. Temperature of surface of the sea, 50° F. (10° C.).

May 19.—One of the above ova still alive: the blastoderm had completely enveloped the yolk, and the dorsal rudiment with Kupher's vesicle was completely formed. Temperature in hatching jar, 53°·0 F. (11°·7 C.).

March 23, 1889.—Several thousand soles' ova fertilised off the Land's End promontory at 7 a.m. Temperature of the sea water at surface, 48°·2 F. (9°·0 C.). Eggs placed in hatching jar at the Laboratory the same evening.

March 24.—Examined the eggs; found segmentation completed, the blastoderm commencing to spread over the yolk. Temperature of water in the hatching jar, 50°·1 F. (10°·1 C.).

March 25.—Blastoderm covering three-fourths of the yolk. Temperature the same.

March 26.—The yolk completely enveloped by the blastoderm, stage shown in Pl. XV, Fig. 4.

March 27.—Eggs all dead.

March 29.—Six soles' ova obtained from surface of the sea in stage just after the closing of the blastopore, that is, after the envelopment of the yolk by the blastoderm. Placed in a small jar with water at 50°·3 F. to 53°·6 F. (10°·2 to 12° C.).

April 5 and 6.—Three of the above eggs hatched.

The eggs last mentioned were at about the same stage when first obtained as the previous lot when they died. It may be inferred therefore that at the temperature above given, about 50° to 53° F. (10° to 12° C.), soles' eggs would hatch ten or eleven days after fertilisation. The following experiment is more complete:—

April 11.—12.5 a.m. Several hundred ripe eggs obtained from soles trawled south of the Wolf Rock: artificial fertilisation attempted with testes taken from the males and crushed in the water. Temperature of surface water of the sea, 48°·5 F. (9°·2 C.).

April 13.—Eight of the above eggs found to be fertilised and developing; temperature of the water in the bottle in which they were carried, 9·5 C. These were transferred to a small jar in the Laboratory; temperature, 10°·0 C. Density of the water brought from south of Wolf Rock, 1·0271. Density of aquarium water, 1·028.

April 16.—Two of the eggs killed for investigation; one died. Temperature in aquarium, 9°·0 C.

April 17.—Temperature in aquarium, 9°·2 C.

April 18.—Temperature in aquarium, 9°·7 C.

April 20.—Two of the eggs hatched out.

Thus two of these eggs hatched on the tenth day after fertilisation in water at a temperature of 48°·0 F. to 50°·0 F. (9° to 10° C.). Now, as I have shown, the spawning period of the sole terminates sooner or later according to the temperature of the sea, and scarcely any ova are shed after the temperature has risen to 50°·0 F. At the beginning of the spawning period, in the latter half of February, the temperature is

from 43° to 45° F. (6°·1 C. to 7°·2 C.), and at this temperature the ova would probably take between two and three weeks to hatch.

It is certain that the eggs of the sole do undergo the same development at about the same rate in their natural condition as they do in experimental conditions. For the characteristics of the sole's ovum having been observed, namely, the size, the layer of segments in the yolk, and the groups of minute oil globules, it is possible to identify ova found in the sea possessing these characteristics as those of the sole. The surface waters of the sea off the coasts of Devon and Cornwall contain nearly all the year round vast numbers of buoyant fishes' eggs. These can very easily be collected by slowly towing through the water from a boat a conical net made of muslin or silk bolting cloth. Among the eggs so collected those of the sole are found in small numbers in March and April, sometimes at the end of February or beginning of May, but at no other time of the year.

The development of the sole within the egg is rather slow compared to that of some other flat-fishes. The eggs of *Pleuronectes flesus*, the flounder, hatched in my hatching jars in six days at a temperature of 50° F. (10°·0 C.); the eggs of the plaice (*Pleuronectes platessa*) hatched in 10 days at the same temperature; those of *Pleuronectes microcephalus*, the merry-sole, hatched in eight days at a temperature of about 49°·1 F. (9°·5 C.).

I have never found the ova of the common sole very numerous among the pelagic ova collected by means of the tow net. The largest number I have obtained at one time is six: these were taken a little to the south-west of the Mewstone.

The density of the water in which soles' ova are found suspended at sea varies slightly in different places. Examples of water from the sea to the south of the Wolf Rock I have found to be 1·027 (distilled water being 1·0), while samples from the sea off Plymouth, inside the Eddystone, have a density of 1·0267 or 1·0268. I found in my experiments that the sole's ova frequently sank in the aquarium water towards the close of their development, that is shortly before they hatched, and that the larvæ lay on the bottom of the jar after hatching: yet the density of this water was 1·027. This shows that the eggs become heavier as development advances, though the sinking of the eggs is probably hastened in the hatching apparatus by the accumulation of particles of sediment upon them. The eggs themselves certainly float in the sea until they are hatched, for they are frequently taken in the tow net when just ready to hatch.

I have not been able to keep the larvæ alive more than a day or two after hatching. In fact, owing to the difficulties of artificial fertilisation I have never had a sufficient number to experiment with. I have been equally unsuccessful in procuring the larvæ from the sea: it is probable that soon after hatching the larvæ sink towards the bottom. Some of the stages given in the illustrations to this book of the larvæ of other species of flat-fishes show that at first one of the most obvious changes which takes place after hatching is the absorption of the yolk. Nourished by the yolk thus

absorbed the larva developes in all its organs. The pectoral fin grows into a large semicircular paddle, the length increases, the black pigment of the eyes (in the choroid) is developed, and the jaws acquire their definite structure. When the sole is first hatched it has no mouth, and takes no food: the mouth is developed before the yolk is absorbed, but not until the absorption is completed does the young fish begin to feed. The newly-hatched sole is 3·55 to 3·75 mm. long, between $\frac{1}{8}$th and $\frac{3}{16}$ths of an inch. It is perfectly symmetrical, having an eye on each side of its head, and swimming vertically in the water, but it swims with its ventral edge uppermost, because the yolk is lighter than the back of the fish.

The next stage in which I have discovered the young sole is immediately after the completion of its metamorphosis, that is, after it has ceased to be symmetrical and to swim vertically in the water, and has taken to lying flat on the sand, and has both eyes on the right side of its head. I had searched everywhere for larval soles at the bottom of the sea, after the eggs had disappeared from the surface, and had had a special trawl with very small meshes made to capture them with, but could not discover any. At last I obtained some through the assistance of Mr. Matthias Dunn, of Mevagissey, who has been for years the friend and counsellor of all naturalists engaged in the study of British fishes. On April 3, Mr. Dunn sent up to the Plymouth Laboratory a number of young living flat-fishes. I found on examination that these were all *Pleuronectes flesus*, the flounder. Some of these were very transparent and only partially metamorphosed, the left eye being still on the lower side, but near the edge of the head; in others the eye was actually in the edge of the head, looking horizontally outwards. Mr. Dunn said nothing about soles, in fact at this time there were no young soles in process of metamorphosis. Having failed to obtain young soles by trawling, I wrote to Mr. Dunn, and arranged with him to meet him at Mevagissey and examine the place where he caught his young flounders. I went to Mevagissey on May 15, and found that the young flounders were found in thousands, if not millions, in the pools and runlets left at low water during spring tides on the bottom of the harbour. The old harbour at Mevagissey (a new additional outer harbour was then being built) is completely emptied of water at the ebb during springs, and the bottom consists of sandy mud. I went over the harbour with Mr. Dunn, and caught numbers of the young flounders with an ordinary cup. The little fish are in constant motion, some of them continually rising to the surface of the shallow pools in the sand and then sinking again to the bottom. We found a few soles along with the innumerable flounders. Many of the flounders were still transparent and only partially or scarcely at all metamorphosed, but in all the soles the metamorphosis was complete. On this day I only caught three young soles, but the following day Mr. Dunn sent to me at Plymouth fifteen more. These young soles were from 12 to 15 mm. long: their characters are represented in Pl. XVI, 3, which is $8\frac{1}{4}$ times the natural size. They possess nearly all the characters of the adult, the chief exception being that the intestine is simpler and shorter, its coils only

extending back a little behind the anterior end of the ventral fin. The eyes are both on the right side as in the adult. The skin and body are more transparent than in full-grown soles, but the pigment of the upper side exhibits perfectly the arrangement of spots which characterises *Solea vulgaris*.

On May 17, I examined at low water the shores of Sutton Pool and the mouth of the Cattewater in order to find out whether young flounders or soles were to be seen in the tidal pools there, as in the harbour at Mevagissey. I could not find a single specimen, but the next day some boys brought me two specimens of young flounders (*Pl. flesus*) taken at low tide on the shore of Sutton Pool.

These young soles, 12 mm. long, from Mevagissey could not have been more than two months and a half to three months old, if the eggs from which they grew were shed at the middle of February or the beginning of March, that is at the commencement of the spawning period of the sole; and it is very probable that they were only two months old or even less. As the larvæ are not hatched until a fortnight after fertilisation, we may conclude that the metamorphosis occurs within about six weeks after hatching.

At the next spring tides, namely, on May 31, Mr. Dunn sent me up some more young flat-fishes from Mevagissey harbour: among these was one young sole, the only one he could find, it measured $\frac{3}{4}$ in. (18 mm.) in length. After this he could find no more young soles in the tidal pools: they all disappeared, having either left the shore for deeper water, or having become strong enough and active enough to swim away with the retreating tide and avoid being left between tide marks. During the following months I perseveringly endeavoured to capture young soles in their later stages. I trawled with my specially constructed trawl in Whitsand Bay frequently both by night and day, and also in Cawsand Bay and other sandy parts of Plymouth Sound, but I never got any young soles. In Whitsand Bay at night I got a large number of young plaice, pouting (*Gadus luscus*), and other young fishes, but not a single sole.

Mr. Dunn having told me that he believed there were large numbers of young soles in the estuaries of the Fal and Helford rivers, I asked my friend Mr. Rupert Vallentin, of Falmouth, to make investigations and see if he could find any specimens. Mr. Vallentin accordingly made a most careful and complete examination of the two estuaries with the following results. He went to Malpas, a place about two miles below Truro, and there found one man, the innkeeper, who possessed a seine which he used for taking flat-fish. On the 27th July Mr. Vallentin had a series of hauls made with this seine, the meshes of which were so small as only to admit the tip of the little finger. After several hauls the total catch of flat fishes was:

Four Flounders from 8 to 12 inches long,

Four Soles, $5\frac{3}{8}$ inches, $5\frac{5}{8}$ inches, 6 inches, $7\frac{3}{4}$ inches in length.

The two smallest of the soles were sent to me, and I was able therefore to make certain that they were really *Solea vulgaris*.

Mr. Vallentin next on July 29, had a large seine sixty fathoms long and two fathoms deep hauled in the Helford River; two hauls were taken, and a number of red mullet and flounders were taken, but only one sole, which was sent to me. It was $4\frac{9}{16}$ inches in length.

Now it is obviously impossible to believe that young soles which were $\frac{3}{4}$ inch in length on May 31, could have grown to 5 inches in length by the end of July. The growth of flat-fishes is not so rapid as that. The spawning of the plaice at Plymouth takes place in February, and is completed early in March. On June 17, 1889, I obtained a large number of young plaice by trawling at night in Whitsand Bay: these measured $1\frac{3}{8}$ to $2\frac{5}{16}$ inches (3·4 to 5·9 cm.) in length; another specimen which I got from Sutton Pool on September 28, measured $2\frac{7}{16}$ inches (6·2 cm.). On May 16, 1889, I obtained a large number of small plaice from the Cattewater, where I saw them caught in a small seine: these measured $4\frac{3}{8}$ to nearly 7 inches in length. It is evident therefore that these last specimens were more than a year old, namely, fifteen months, and it is obvious that the soles caught by Mr. Vallentin were sixteen months old, reckoning from the end of March as the spawning time. They were soles in the second year of their growth. I have in my collection another small sole, measuring $4\frac{7}{8}$ inches (12·5 cm.) which was caught either in Plymouth Sound or on the trawling ground off Plymouth, at the end of February, 1888. This must have been just a year old.

Why I have failed to obtain soles in the first year of their growth, after the stage of those found at Mevagissey in May, I cannot understand. It may be owing to some peculiarity of habit, that though I obtained young plaice and other species of flat-fishes by trawling in shallow water in Whitsand Bay, I caught no soles. Of course soles in the neighbourhood of Plymouth are much less numerous than plaice, flounders, dabs, or merry-soles (*Pl. microcephalus*), and this doubtless adds to the difficulty of finding them. However, the problem will, I hope, be solved next year.

It has been shown that the young soles spawned in March have completed their metamorphosis by the middle of May, when they are $\frac{1}{2}$ to $\frac{9}{16}$ inch in length (12 to 15 mm.); that on May 31 they are about $\frac{3}{4}$ inch long (18 mm.); and that in one year they grow to about 5 inches in length. We have now to consider their subsequent growth.

Soles of small size but larger than any of those just mentioned are taken in Plymouth Sound in considerable numbers by the small shrimps trawls, which have a beam of 12 to 15 feet in length. Such trawls are regularly worked in the Sound for shrimps and prawns, and one of them is regularly used for the collecting work of our Laboratory. On May 10, 1889, the Laboratory fisherman took with the shrimp trawl in the Cattewater, six soles measuring $6\frac{3}{4}$ to $7\frac{3}{4}$ inches in length (17·1 cm. to 19·6 cm.). Another caught on May 6, measured $9\frac{3}{16}$ inches (23·3 cm.). I consider these soles to be just over two years old. Soles from this size upwards are almost always to be caught in the Sound, but the larger are less plentiful. They are never very abundant, but usually about half-a-dozen can be caught in a day's work.

Adult soles, as sold in the market, vary from about 12 to 16 inches in length (30 to 40 cm.). If we take the medium size, 14 inches (or 35 cm.), it is evident that this size cannot be reached in one year more by soles which at two years are only $6\frac{3}{4}$ to 9 inches in length. In all probability the length of 14 inches is not reached until after the fish is four years old, and at three years it is only about 11 inches long.

The difficulty of distinguishing the ages of soles after the first year is due to the fact that at a given time a series of sizes may be found from those which are probably two years old to those which are three. The explanation of this is, first, that the spawning time lasts altogether at least two months, and that the rate of growth doubtless varies in different individuals according to the amount of food they have been able to obtain.

The largest sole I have ever seen was one I obtained when trawling off the Land's End in March, 1889. It was a ripe female, and measured $20\frac{1}{2}$ inches in length, $9\frac{1}{2}$ in breadth (52 cm. by 24 cm.). But still larger specimens have been recorded. According to Day a Mr. Grove, of Charing Cross, received one from Torbay in 1882, which was 24 inches (61 cm.) long, and weighed $6\frac{1}{2}$ lbs. Yarrell mentions one taken to the Totness market in 1826 which was 26 inches (66 cm.) long, $11\frac{1}{2}$ inches (29·2 cm.) broad, and weighed 9 lbs. Probably the sole, like most fishes, goes on growing as long as it lives, and taking the growth as 3 inches a year after the first year, when it grows 5 inches, the fish I saw, which was $20\frac{1}{2}$ inches long, must have been six years old.

PART IV.

ECONOMICAL.

CHAPTER I.

ARTIFICIAL PROPAGATION.

The commonest and most obvious method of attempting to increase the supply of a valuable fish is to hatch its eggs. The young when hatched may be disposed of in one of two ways. They may be kept in captivity and regularly supplied with food until large enough to be valuable, or they may be set free in the natural haunts of the species so as to replenish its numbers. The question of the best way to increase the supply of soles will be fully discussed subsequently. At present I shall describe my own experiments on the artificial propagation of the species.

In the case of a number of species of valuable marine food-fishes there is no great difficulty in obtaining large numbers of eggs from the fish, fertilising and hatching them. The eggs become ripe at the spawning period, and it is perfectly easy to tell whether the eggs of a given species are ripe or not. The number of eggs which ripen at one time varies in different species. In some, as the herring, nearly all the eggs become ripe simultaneously. When the eggs are ripe they can be squeezed out of the ovary by gently squeezing the abdomen of the fish with the fingers and thumb. They run out in a continuous stream, and no blood or membranes escape with them: if the eggs are not ripe no eggs escape unless considerable pressure is applied, and when they are forced out they are accompanied by blood and by membranes containing blood vessels. When the eggs in the ovary all ripen simultaneously, or nearly so, as in the herring, the ovaries can be entirely emptied by gentle pressure. In all fishes that I have examined, the number of eggs ripe at the same time increases after the spawning has commenced, so that the ovaries after a certain number of eggs have been shed contain ripe eggs only and can be entirely emptied. In the cod family the ripening of the eggs goes on very gradually, so that only a portion of the eggs in the ovaries of a female can be pressed out at one time. The eggs of the sole ripen gradually at first, but after spawning has commenced and some of the eggs have been shed the rest all ripen simultaneously. The eggs also seem to be shed as soon as they are ripe. These are the conclusions I form from my experience, which is that I have usually met with soles whose ovaries were either full of unripe eggs and yielded very few which were ripe, or else were quite empty, all the eggs having been shed.

I commenced my experiments on the sole in 1888. At my first attempt, which was

on a trawler to the west of the Eddystone on February 6, I got a few, very few, ripe ova, and could get no milt by squeezing any of the fish. I did not then know that the testes were small and the milt small in quantity in the sole. Only two or three of the ova then obtained were found to be floating in my bottles when I returned to shore, and none of these were fertilised. My next attempt was on March 6 and 7, when I was on a trawler to the S.E. of the Wolf Rock. Only two or three females out of nearly a hundred were then found to yield ripe ova, and as I could squeeze no milt from the males, I cut out the testes, cut them into two or three pieces and placed them in the bottles with the ova. On my return to Plymouth on March 8, I found only about a dozen ova floating, and of these only two or three were fertilised and showing the commencement of development. I made another attempt on the same fishing ground between April 3 and 7, but on my return found that not a single ovum was fertilised. On this occasion I got a considerable number of ripe eggs altogether, but only a few from each fish. From May 15 to 18, when I was in a trawler on the same ground, we had very bad weather: nearly all the soles were spent, but some ripe ova were obtained from one specimen, and three or four of these were found to be fertilised by the pieces of testis.

It seemed therefore from these experiments made in 1888 that the artificial fertilisation of soles' ova was a matter of the greatest difficulty. I had succeeded in ascertaining the characters of healthy fertilised ova from the few I had been able to procure, and was therefore able to identify the sole's ovum when it occurred in the produce of the tow-net, and I had also observed and made drawings of some stages of the development, but this, though valuable knowledge, brought me very little nearer to the practical object of my experiments.

In the season of 1889 I continued the experiments. I had found that soles were scarce on the Plymouth trawling ground, which extends from the Dodman Point in Cornwall, to the neighbourhood of Bolt Head in Devon, both inside and outside the Eddystone. On this ground very often no soles at all are found in a haul of the trawl, and when there are some very often all are immature, or when a ripe female is taken there are no males. On February 12, 1889, I was on a trawler which towed her trawl from off Looe to a point south of the Plymouth Breakwater lighthouse: four soles were taken in this haul of which only one was adult, and that not ripe. On March 14, I went out again, and this time the trawl was worked about 10 miles south of the Eddystone. Two hauls were made: in the first there was one sole, in the second none, although the first haul was made in the night. After this I heard that some of the Newlyn mackerel boats were working small trawls in Mount's Bay in order to earn something while waiting for the commencement of the mackerel season. I therefore went down to Penzance by rail, taking with me a number of collecting bottles to bring back soles' ova. I went out in one of the boats on March 22. On this occasion I examined the testes very carefully. I tried a large number of males, and could not squeeze from any of them the thick milk-white milt which is so characteristic of the

ripe males of other fishes I have examined. Liquid came from them of course, and in some cases it had a slightly milky appearance, but it was never possible to distinguish the milt derived from the testes from the urine coming from the urinary bladder. It was therefore useless to squeeze a male sole over a bottle containing ova in order to fertilise them, for it was impossible to know whether any milt entered the bottle or not. I dissected out the testes themselves from several specimens, and cut them in half and crushed them between my fingers, and found that all the liquid that came from them was thin and almost clear, only very slightly turbid. It is evident, therefore, seeing that these testes came from ripe males, that the sole does not produce any milk-white thick secretion such as constitutes the milt of other fishes. The milt of the sole is not only very limited in quantity, but is a thin liquid only slightly turbid, which is difficult to distinguish when the male is squeezed. A considerable number of soles were taken on this excursion. Some of the females were spent, some unripe, some yielded only about a dozen ripe ova. But one female, the largest specimen I ever saw (*see* page 126) yielded several thousand ripe ova. The ovaries of this specimen contained ripe ova only: she was at the last stage of spawning, and probably these ripe eggs were nearly half the entire number produced that season, the rest having already been shed. Having fully investigated the males I concluded that the only method likely to ensure fertilisation was to extract testes from the male soles, and crush these up into a pulp between my fingers in the water into which the ova were to be allowed to fall. In this way the whole of the milt contained in the male organs was sure to be set free in the water containing the ova. I found this method perfectly successful.

At the Laboratory there was now a constant circulation of sea-water, and apparatus for hatching floating ova which had been found to work admirably. The year before the Aquarium was unfinished and there was no constant supply of sea-water. I landed at Penzance with fertilised soles' eggs on the morning of March 23. The eggs were contained in short wide glass jars such as are used for conveying sweets: over the mouth of each was tied silk bolting cloth to prevent the eggs escaping, and this, to some extent, prevented the water splashing over. I placed the bottles, held in a divided basket, in the break-van of a train, and took them to Plymouth, where I arrived the same evening. The eggs were at once placed in the hatching jars; they seemed quite healthy, and microscopic examination showed that they were all fertilised.

The apparatus and method I adopted last spring for hatching floating eggs were as follows:—The apparatus is a modification of that recommended by H. C. Chester, of the United States Fish Commission.* The arrangement of Chester's apparatus is represented in Fig. *E* (p. 132): it consists of a tall glass jar, *j*, which has an open narrow neck above and is widely open below. This is placed in a tank having a constant supply of sea-water, the overflow of which takes place through a siphon tube, *s*, having a diameter greater than that of the inflow. The water in the jar is of course always at the same

Vide "Devel. Osseous Fishes," by J. A. Ryder, Rep. U. S. Fish Commission for 1885, p. 499.

level as the water in the tank. When the siphon of the outflow tube is empty the water in the tank and jar rises until the level of its surface reaches the bend of the siphon. Then the siphon fills and commences to act and the level of the water sinks gradually until it falls below the short leg of the siphon, when the latter empties and the outflow stops. The wide opening at the bottom of the jar is covered with a single thickness of coarse cheese cloth to prevent the escape of the eggs which are introduced into the jars through the narrow opening of the neck above. The rise and fall of the water is only five inches vertically. Ryder says that cod eggs were hatched in this way with a loss of only five per cent. I tried this apparatus with a large number of eggs of the flounder and plaice (*Pleuronectes flesus* and *P. platessa*).

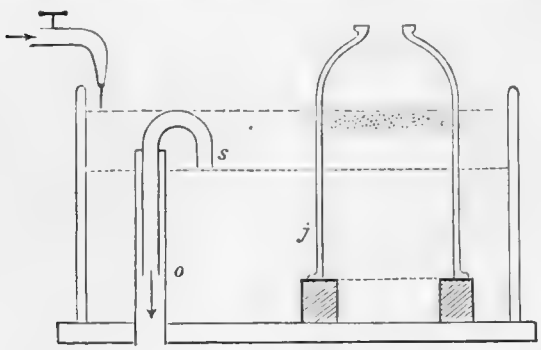


Fig. *E*.

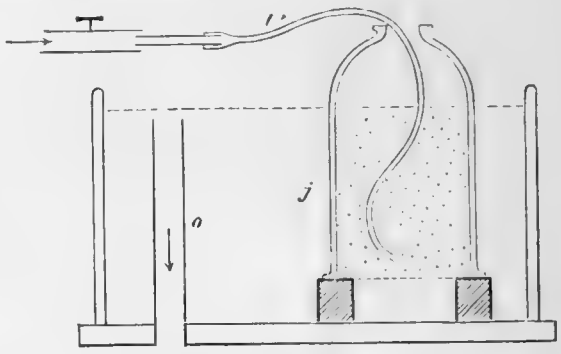


Fig. *F*.

Fig. *E*. Diagram of a transverse section of an apparatus for hatching buoyant fish eggs, arranged according to the method devised by Captain Chester, of the United States Fish Commission.

Fig. *F* exhibits the modification of the apparatus adopted in the Laboratory of the Marine Biological Association.

j, The glass hatching jar, resting on two bricks in a small tank containing sea-water; *o*, the overflow tube; *s*, siphon in the overflow tube; *t*, an indiarubber tube conducting the inflowing water into the interior of the hatching jar. The dots represent the eggs.

On February 12 I placed a large number of ova of the flounder, artificially fertilised the same day, in two glass jars of the form described. The jars were 8 inches wide and 17 inches high. The bottom of each jar was covered with silk bolting cloth. Each jar was supported on two bricks resting on the bottom of a shallow aquarium tank made of slate and glass. The water escaped from the tank by a stand pipe into which I fitted a glass siphon so that the level of the water in the tank oscillated between limits about 4 inches apart. The water inside the jar was of course perfectly still: its gradual rising and sinking caused no disturbance in it, in fact I found that the upper part of the water in the jar was scarcely changed or affected by the rise and fall. This will readily be understood. The total height of water in the jar was about 10 inches: at the top of this floated the eggs which formed a layer about $\frac{1}{4}$ inch thick. As the level of the water in the tank sank, the water at the bottom of the jar escaped through the bolting cloth. When the tank was at its lowest level the height of the water within the jar was still 6 inches. When the water rose again all this water was bodily lifted up with the layer of eggs at its surface, while 4 inches of new water

entered the bottom of the jar. Thus the 6 inches of water simply rose and fell gradually without being renewed or circulated: the only change effected in it was that which took place at the bottom layers by contact with the new water which entered the jar every time the level of the water rose. The upper layer of water containing the ova was practically stagnant. The fall and rise of the water occupied each three quarters of an hour.

On February 16 I found that about half the ova in each jar were dead, lying on the bolting cloth at the bottom and contaminating all the water that entered the jar. I therefore removed these dead ova by means of a siphon, and changed the arrangement in one jar. I left the jars in the same position, but removed the siphon from the overflow pipe of one tank and introduced into the jar (Fig. *F*) an indiarubber tube, *t*, leading from a jet supplying clean sea-water. I regulated the force of the water discharged by the indiarubber tube. The tube reached just below the lowest level to which the water in the jar sank, and the force of the water escaping from it kept the ova in constant but very gentle motion. Thus clean water was constantly entering the jar and escaping through the bolting cloth at the bottom, and the eggs were separate in the water, not in contact with one another in a dense layer.

On February 17, I found that all the ova in the unaltered jar, except a dozen or two, were dead, while in the jar provided with the new arrangement, only a dozen or two out of several thousand had died. But I found that the new arrangement was not perfect. The water when its surface fell in the jar left a number of ova adhering to the sides of the jar, which were thus for a considerable time out of water. These eggs so stranded died. I therefore placed the jar in another tank in which there was no siphon in the overflow pipe, so that the water in the tank and jar was at a constant level. I made the indiarubber tube delivering inside the jar longer so that the water escaping at its end threw it into a regular gentle rhythmical motion which served to keep the ova uniformly distributed throughout the water in the jar. I found this method answered perfectly. The water in the jar was constantly renewed, and, a very important point, no sediment settled on the ova. In fact, the eggs thus treated were as clean and transparent as eggs taken by the tow-net from the sea, a result I never before obtained with eggs artificially treated.

On February 18, I found all the ova in the new apparatus had hatched; in the jar left with the original arrangement a few eggs were still alive and some of these were hatched, but not all. It seems therefore that the motion of the eggs facilitates hatching, as it enables the larva to get rid of its egg shell more easily than it can in still water. The number of larvæ hatched in the unaltered jar was quite insignificant, not more than a dozen altogether, while in the altered arrangement I had between one and two thousand healthy larvæ. The two jars originally contained about the same number of eggs. In a third jar I had placed, on February 12, a large number of fertilised ova of the plaice. This jar was arranged on the American plan, and was left in this condition without change. On February 19, only about twenty

of these eggs remained; the rest had all died, notwithstanding that I took care to remove all dead eggs every day.

The arrangement which I adopted and found perfectly satisfactory is shown in the diagram, Fig. *F*. It may of course be carried out on any scale, and does not require a great deal of space. It is better to increase the capacity of the apparatus by increasing the number of the jars rather than by increasing the size. Jars larger than those I have described become unwieldy.

I found the method suited the hatched flounder larvæ extremely well: they lived in the jars in perfect health until the yolk was entirely absorbed. I did not succeed in feeding them after that period. It would probably be necessary when the yolk was absorbed to turn them out into a larger tank, as feeding in a confined space contaminates the water. A few of the plaice eggs hatched on February 22, and one or two of them lived till the yolk was absorbed in the apparatus arranged on the American method; but this was the total result out of several thousand ova.

To return to the eggs of the sole which I obtained in Mount's Bay on March 23. I placed them in two hatching jars arranged in the way I have described. There were several thousand of the eggs, but I did not count them. As I have said, they were all fertilised and had commenced to develop when placed in the hatching jars. On March 24, when I examined them, I found to my surprise that nearly half in each jar were dead. The blastoderm in the dead ones was formed, but some abnormal appearances were seen round its edge. I removed the dead eggs, and hoped the mortality was over and that the rest would live. But the next day I found again half of those left had died. In the living ones the germinal membrane had enveloped more than half the yolk: many of them seemed unhealthy. On March 26, only about six eggs in each jar were left alive, and these were dying, although in them the embryo was already formed. As I had succeeded in keeping eggs of the sole, artificially fertilised, alive for a considerable time with only the roughest apparatus, and as I afterwards hatched eggs taken by the tow-net from the sea, the cause of death in the above experiment clearly could not be attributed to the water of the aquarium or any of the conditions under which the eggs were kept after they were brought to the Laboratory. I could only attribute it to the railway journey which had shaken and jolted the eggs and so injured them mechanically. It might be suggested that there was too great a difference of temperature between the water in which the eggs were carried from Penzance and the water of the hatching jars, but other experiments showed that eggs taken from the sea lived well in the sea water of the Laboratory, and the weather during the railway journey was neither hot enough to heat the water in the jars containing the eggs nor cold enough to cool it to any extent.

Believing it useless to carry fertilised eggs by rail, I went out on April the 8th, on board a trawler which was going to fish on the Mount's Bay ground. On April 11, 12.5 a.m., the trawl was hauled with seventeen soles in it. Of these I examined

eleven, the rest were not found till afterwards when the decks were cleared up. Of these eleven, three were females almost spent but still containing some ripe ova; one was a female still unripe, four were spent females, and three were males. I got 300 or 400 eggs altogether which I tried to fertilise as before by crushing testes in the water. At 4.30 p.m. the same day from six soles taken I got about a dozen more ova. On April 12, at 8 a.m., after a good night's haul, fifty-seven soles were brought on deck. Of these fifteen were small, under nine inches in length, and not sexually mature; eighteen were males; nineteen large females entirely spent; five large females, which yielded a few ripe ova.

I may conveniently refer to the eggs obtained from the different hauls of this cruise as lot 1, lot 2, and lot 3. On April 12, while still at sea, I observed that a large proportion of the eggs of lot 1, fertilised the previous day, had died and sunk. These were probably not fertilised, but I do not know why the fertilisation had failed; it may have been because the males were either immature or spent. I found when I returned to the Laboratory, on April 13, that only eight eggs in lot 1 were alive and developing; in lot 2 some were floating but none fertilised; in lot 3 two or three ova were alive and developing.

On April 15, there were altogether nine eggs left alive: of these I preserved two for microscopic examination and left the other seven in a small glass jar provided with a circulation, not in one of the hatching jars above described, but an ordinary jar, the only difference in the arrangement being that the overflow of the water took place through a protected siphon, the jar standing in the air, not in the water of a tank. On April 16, I again went to sea, and returned on April 20, when I found of the seven eggs I left in the Laboratory two were hatched, two alive but unhatched, and the rest dead. The circulation had almost stopped, the supply tube having got choked. On April 21 the two larvæ were dead, and one of the eggs: the last egg hatched on April 22, but died the same day.

The above results prove that it is possible to artificially fertilise the eggs of the sole and to hatch the eggs so fertilised in a hatching jar provided with a circulation. They prove also that the cause of the death of the large number of eggs brought from Penzance was not in any of the conditions to which they were exposed in the Laboratory. The reason that I did not place the seven eggs just mentioned in a large hatching jar was that it is difficult to find such a small number in such a jar, or extract them for closer examination.

Postscript (May 3, 1890). While these pages have been passing through the press the spawning period of the sole has again arrived, and I have renewed my endeavours to perfect a method of artificial propagation. In consequence of previous experience my success has been greater than in former seasons. During a week I spent on a Lowestoft trawler in the Bristol Channel from April 9 to April 16, I obtained a large number—hundreds of thousands—of ripe soles' eggs.

I tried to fertilise these in the usual manner by extracting the male organs and crushing them in the water containing the eggs. On my return, I found less than half the eggs taken were floating, but only about half of these last proved to be fertilised. However, those which were fertilised were hatched in the hatching jars without difficulty, and I obtained thousands of larvæ. Some of the eggs were lost before hatching because they ceased to float, and many larvæ were lost for a similar reason, as they began to sink two or three days after hatching. However, a large number of the larvæ were successfully kept alive until the mouth had developed, the yolk was almost entirely absorbed, and feeding had commenced. Then they all died. Thus when the eggs are once fertilised they can be hatched without difficulty.

CHAPTER II.

THE SOLE FISHERY.

We have next to consider the present condition of the sole fishery and to ascertain whether the supply of soles in British waters has decreased in recent times. The materials available for this enquiry are extremely scanty. Fishery statistics have been systematically recorded for many years past in Scotland, but as there are no soles, except as occasional rarities, in Scottish waters, these statistics are of no use for our present purpose. The statistics of Irish fisheries on the other hand have only been collected at all comprehensively since 1887, and the quantity of soles and other fish landed at a *certain number* of Irish ports is recorded for only two years up to the present time, namely, 1888 and 1889. For England and Wales analytical statistics have been published in the "Statistical Tables and Memorandum relating to the Sea Fisheries, &c." compiled by the Fisheries Sub-department of the Board of Trade, since the year 1886. The figures in these tables of the total quantities of soles and other prime fish landed on the English and Welsh coasts in successive years are given in the following table:—

	Soles.			Turbot.			Prime Fish not separated.		
	Quantity. Cwts.	Value. £	Average price per cwt.	Quantity. Cwts.	Value. £	Average price per cwt.	Quantity. Cwts.	Value. £	Average price per cwt.
			£ s. d.			£ s. d.			£ s. d.
1886 . .	98,078	427,452	4 7 2	59,850	182,665	3 1 0½	370,014	369,089	0 19 11½
1887 . .	85,316	389,414	4 11 3½	63,166	184,662	2 18 5¾	115,850	368,674	3 3 7¾
1888 . .	72,522	379,382	5 4 7½	55,041	171,967	3 2 5¾	113,415	316,966	2 15 10¾
1889 . .	74,143	431,269	5 16 4	53,576	180,841	3 7 6	35,982	126,924	3 10 6½

	Totals of Prime Fish.			Totals of all Fish except Shell-fish.		
	Quantity. Cwts.	Value. £	Average price per cwt.	Quantity. Cwts.	Value. £	Average price per. cwt.
			£ s. d.			£ s. d.
1886	527,942	979,206	1 17 1	6,412,433	3,688,079	0 11 6
1887	264,332	942,750	3 11 4	6,029,481	3,778,958	0 12 6½
1888	240,978	868,315	3 12 0¾	6,348,072	3,948,013	0 12 5½
1889	163,701	739,034	4 10 3	6,464,564	3,862,389	0 11 11½

All the above figures, according to the explanation given by the officials who publish the statistics, refer to the fish as landed; the prices are the "wholesale values at the places of landing," by which I believe is meant the prices actually paid to the auctioneers who sell the fish for the fishermen and smackowners. The classification is made according to the way in which the fish are packed when brought ashore. The best and the largest quantity of the soles and turbots are placed in boxes by themselves not mixed with any other fish, while if there are not sufficient soles or turbots in a catch to make it worth while to pack them separately they are put together with other kinds of "best" or "prime" fish. Therefore the figures under the heading "soles" do not represent the total quantity of soles landed. There are tons of soles and turbot included under the heading of "prime fish not separated." Now, if we look at the figures referring to soles only, we find that in the three years 1886, 1887, 1888, there was an annual decrease of 13,000 cwt., a very startling result. But in 1889 there was an increase of nearly 2,000 over 1888. But this latter increase is much more than balanced by the enormous decrease in the quantity of miscellaneous prime fish in 1889, a decrease of 77,433 cwt. In no year was the decrease in the quantity of separated soles balanced by an increase in the quantity of miscellaneous prime fish; on the contrary, there was a steady decrease in the latter in 1887, 1888, and 1889. The figure of this item in 1886 must be kept apart, for in five months of that year haddock were included under it at Billingsgate when packed with prime fish, while since then haddock have been estimated separately. This alteration also affects the totals of prime fish; but neglecting 1886 there was a great annual decrease in the total quantity of prime fish landed. There is no doubt therefore on the whole that since statistics have been kept, since the year 1886, there has been a steady decrease in the quantity of soles landed on the coast of England and Wales. I think it is very probable that the slight increase in the quantity of soles landed separately in 1889 is due to the fact that in the earlier half of this year a large number of North Sea trawling smacks left their own grounds and went to work off the north coast of Cornwall, on a trawling ground which had previously been almost entirely neglected, and on which soles were found in great abundance. This ground was first tried by some Brixham trawlers in 1887.

Another sure indication of the increasing scarcity of soles is the steady rise in price. The price of soles sold separately has risen 4*s.* to 13*s.* per cwt. every year. The price of turbot has not increased so steadily, though there is indication of increasing scarcity of this fish also. The price of mixed prime fish is somewhat irregular: that of the year 1886 is of no value to our inquiry for the reason before mentioned, and the prices in other years may and probably do vary with the proportion of soles in the boxes. The average price of prime fish taken altogether has increased steadily. In 1889 it was 18*s.* 3*d.* per cwt. greater than in 1888. The Board of Trade tables give the average price of soles per lb. for each year, and it is interesting to compare these with the prices for the ten years 1856 to 1865. In the report of the Sea Fisheries

Commission of 1866 I find a table giving the price of various kinds of fish during those years both in the Manchester Fish Market and that of Newcastle-on-Tyne. The figures are as follows:—

Manchester. Soles per lb.	1856.	1857.	1858.	1859.	1860.	1861.
	3*d.* to 4*d.*	6*d.* to 8*d.*	5*d.* to 8*d.*	6*d.* to 10*d.*	4*d.* to 6*d.*	6*d.* to 8*d.*
	1862.	1863.	1865.			
	6*d.* to 8*d.*	8*d.* to 10*d.*	6*d.* to 8*d.*			
Newcastle. Soles per pair	1856.	1857.	1858.	1859.	1860.	1861.
	9*d.* to 1/3.	1/- to 1/6.	1/- to 1/6.	1/3 to 1/9.	1/3 to 1/9.	1/3 to 1/9.
	1862.	1863.	1864.	1865.		
	1/6 to 2/-.	1/6 to 2/-.	1/9 to 2/-.	1/9 to 2/-.		

Thus the price in both places was about doubled in the ten years. The average prices of soles per lb. in the past four years according to the Board of Trade returns are:—

1886.	1887.	1888.	1889.
9·34*d.*	9·78*d.*	11·21*d.*	12·46*d.*

To compare these with the Manchester prices given above it must be remembered that the latter prices are retail, or very nearly so: that is, they are the prices of the fish after they had been carried from the landing place to Manchester, and therefore include the cost of carriage and the profits of the merchants and salesmen. Thus the rise in the price of soles since 1856 is at least from 3*d.* to 1*s.* per lb., or fourfold: and this is not due to any decrease in the value of money, for almost everything else has become cheaper.

It may be urged that the total quantity of all fish landed has not decreased but only slightly fluctuated. But this is no compensation for the scarcity and dearness of soles. It may be partly due to the greater value of second rate fish caused by the diminution in the supply of prime fish, and it may be partly due to the fact that many kinds of fish such as herrings, mackerel, and pilchard vary considerably in abundance in different years from causes which are apparently not connected with fishing operations. But soles are stationary fish: they do not move in shoals, nor as far as we know move about at all to any great distance, and the only cause to which we can attribute the decrease in the supply is constant fishing. The decrease is certainly not due to any decrease in the numbers of trawlers, for the trawling fleets grow larger almost every year.

The statistics I have discussed are as far as I can discover all that are available. As a nation we ought to be thoroughly ashamed that no statistics worth the name were kept either in England or Ireland before the year 1886. Before that time there were periodical agitations about some particular kind of fishing which was said by those not engaged in it to be injuring the fisheries. These agitations usually arose out of jealousies between different classes of fishermen, and were founded chiefly on prejudice and

ignorance. The Government of the day appointed Royal Commissions to inquire into the questions in dispute. These Commissions proceeded to investigate the matter not by considering the facts, for there were usually none established either of a statistical or biological character, but by taking down carefully and printing the statements of the disputing fishermen themselves and weighing the assertions of one set against those of the other. Of course the Commissions collected together those facts bearing on the matter which were known, and their reports contain a certain amount of grain amongst a great deal of chaff. They also constantly reported that the only satisfactory method of investigating problems concerning the fisheries was to study the natural history of the fishes and to record fishery statistics. Probably the various Commissions cost quite as much as a proper fisheries department, including a scientific as well as a statistical staff, would have cost, but it was the traditional British method to appoint Commissions. The public authorities have now commenced to collect and record statistics, but they are yet far from the organisation of a satisfactory and convenient system. In order to find information about the English sea-fisheries now we have to search three distinct publications; the statistics of fish landed are given in the "Statistical Tables and Memorandum," the number of boats and men are to be found in the Annual Statement of Navigation and Shipping, the preparation of which is entirely out of the control of the Fisheries Sub-department, and finally a certain amount of miscellaneous information is given in the Annual Reports of the Inspector of Sea Fisheries.

But apart from this inconvenience a great deal of improvement might be effected in the system of recording the statistics. The difficulty of finding the total quantity of soles landed has been sufficiently obvious from the above discussion. It might at first be supposed that all the soles landed were included under the heading "soles," but we find on careful examination that some soles are also included in the item of "prime fish not separately distinguished." Of course this inconvenience is due to the customs of the trade: sometimes soles are sold in trunks unmixed with other fish, while boxes of mixed fish, including soles and small turbot, are also sold entire. But at least some effort might be made to ascertain and inform the public what proportion the soles sold separately bear to the total amount, whether the proportion is approximately constant or not. If it has been found possible to separate the haddocks which are sent to Billingsgate packed with prime fish, it ought to be possible to separate the soles. Another peculiarity in the tables which must shock the mind of anyone engaged in the fish trade on the east coast or in London, is that beside the item soles in the figures for England and Wales is placed an item in the figures for Scotland which a foot-note explains to refer to lemon-soles. Now lemon-soles are no more soles than plaice are, and their value is scarcely greater than that of plaice. Besides, quantities of lemon-soles are sold in the London market and other English markets, but we are not told where they are placed in the English statistics. We do not even know whether they are classed as "prime fish not separately distinguished" or not. However, it is very satisfactory

that complete statistics are now annually recorded, and it ought to be possible in future to find at once whether the supply of a given fish has decreased or increased: the importance of this possibility in relation to the trial of any measures, legislative or otherwise, intended to maintain or increase the abundance of particular kinds of fish, cannot be over estimated.

CHAPTER III.

PRACTICAL MEASURES.

The question we have here to consider is: Can soles be made more plentiful by measures which are not only possible but practicable, that is, which are sufficiently easy to be carried out, when they are understood and have become familiar, without a degree of exertion and expense too great in comparison with the results gained? In examining into this problem we must distinguish the two ways in which human action can be applied to a valuable wild animal. One way is to keep the animal under entire control by taking it into captivity: this may be called domesticating the animal, the word domestication being used with a wide signification, and not necessarily implying the taming of the animal. The other way is to leave the animal in perfect freedom, and to increase its numbers by protecting it and promoting its reproduction. With regard to the sole we will consider the latter method first.

At present our knowledge is much too scanty to allow us at once to reach definite conclusions and calculate with certainty the effects of measures which suggest themselves. We do not know exactly what proportion of soles are usually destroyed in nature at different stages of their existence: the proportion which reach adult age from a given number of eggs must, we know, be very small.

We know that the "prosperity," if I may use the word, of a species depends on a chain of extremely delicate relations between it and the other species of the fauna and flora of its habitat: and we have reason to infer that in some cases these relations and the species themselves are affected to an enormous extent by physical, *i.e.*, meteorological conditions over which man has no control. In order to know how man's action can increase or maintain the abundance of a species we require to know how his action in the past has decreased its numbers. Professor Huxley, in the case of the herring, for instance, has argued that enormous as is the number of herrings captured annually on the coasts of Britain, the evidence leads to the conclusion that the number destroyed by man is quite insignificant in comparison with the numbers destroyed by the natural enemies of the herring—by the cod and sea-birds and other animals which prey upon it. And this conclusion seems to be supported by a comparison of the abundance of herrings in different years. The number of herring fishermen, the efficiency of their boats and nets, and the extent of their operations has

increased steadily and largely during the past twenty years. But although herrings have been somewhat scarcer in some years than others, there is absolutely no evidence that the supply has gradually decreased. On the contrary, the following figures will show that the supply has on the whole increased as the number, efficiency, and size of boats and nets increased, but has not increased continuously in proportion to the increase in the apparatus of capture, nor decreased after a certain maximum in consequence of the great number annually captured. In fact as far as we can see at present the abundance of herrings in different years fluctuates in consequence of conditions not only beyond human control, but at present unknown. The number of barrels of herrings cured in Scotland was :—

In the year	1870	833,160
,,	1874	1,000,561
,,	1879	841,796
,,	1880	1,473,600
,,	1881	1,111,155
,,	1884	1,697,952
,,	1888	1,118,872

But, on the other hand, we know that human rapacity and recklessness have entirely or nearly exterminated certain species of animals which were at one time very abundant in certain regions. The Dodo and the Rhytina were exterminated by man, and the Greenland whale and the American bison seem to be rapidly approaching the same end. The Dodo was confined to the island of Mauritius, and seems to have been more persecuted by the domestic animals introduced by the Dutch discoverers of the island than by the Dutch themselves: it could only have been saved by being domesticated, and apparently it was not sufficiently valuable to be worth keeping. The Rhytina was a kind of Manatee which lived on Behring's Island and Copper Island in the North Pacific, and was extremely numerous on the former in 1741, when the island was first discovered. It was exterminated in less than fifty years by Russian hunters and traders who lived upon its flesh. The Rhytina was of enormous size, and quite harmless, and its extinction was doubtless largely due to these circumstances, which made its slaughter easy, and to its slow rate of multiplication.

The history of the northern fur seal of the Behring Sea is less mournful, and at the same time most interesting and instructive. This species, *Callorhinus ursinus*, breeds only on two islands of the Pribylov group off the coast of Alaska, on the Commander Islands in Behring Sea, and one other in the same region. The seals arrive at these islands late in spring, and remain on shore until the beginning of November. The females bring forth their pups soon after landing, and before the mothers leave the islands these pups are weaned, and able to travel with them. During the winter months the seals seem to disperse and live in the sea, but I have found no account of their mode of life during this period. In 1870 the Alaska Commercial Company of San Francisco received a lease

of the Pribylov Islands from the United States Government at a rent of $55,000 or £11,000 a year, and afterwards rented the other seal islands from the Russian Government. This company since that time has slaughtered 100,000 seals annually on the Pribylov Islands alone, for the sake of their skins, and yet has not diminished in the least the abundance of the animals, but rather increased it. Yet it is practically certain that if the seal islands had been open to hunters of all nations, considering the great value of the skins, the numbers of the species would by this time have been seriously diminished, and probably the species would ultimately have been exterminated. What is the reason of the different results obtained by the Company? It is the story of the goose with the golden eggs. The old male seals are polygamous and very pugnacious, and do not allow the young males to possess any wives at all. The young bachelors live in a herd by themselves, and only these are killed; no females are destroyed. The check on the number of males is an advantage to the species, for when there are too many, the amount of fighting that goes on in the "rookeries" destroys a number of cubs.

In the case of this fur seal a whole species has been practically made private property without being in any sense of the word domesticated. It is evidently impossible for a company to acquire exclusive possession of the whole of any species of marine fish. But our marine fisheries are the property of the nation, and the fishermen can be controlled by legislation, if measures can be found which have such a relation to the conditions of life and reproduction of the various species as to result in benefits both to the fishermen and the whole nation.

Legal measures have from time to time been taken to prevent the reduction of the numbers of valuable marine animals by prohibiting the capture of the young individuals below a certain size. Such measures doubtless have a good effect when carried out, for, in the first place, small individuals have generally a very small value, while the same individuals when full grown are worth many times as much; and, in the second place, if the young individuals are destroyed there will be no parents to succeed those from which they were derived. But these measures, however effectively carried out, will not prevent the scarcity of a species if the adults are constantly destroyed in such numbers that there are not enough left to produce sufficient eggs to give rise to the next generation. The latter has been the case with species of fish which ascend rivers and estuaries in order to breed. A measure applied to prevent the too great destruction of adults in this case is that of prohibiting the capture of any individuals whether young or adult during the breeding period, the institution of "close seasons." Now if the regulations concerning close seasons were carried out in regard to the salmon in such a way that no adult salmon in a river in a given winter were killed until after it had spawned, and all were killed after spawning, and at the same time no immature fish were killed, it is clear that the result would be that each fish that arrived at maturity would certainly breed once, and only once. And there seems no reason why this should not be sufficient to maintain the abundance

of the species; for the number of eggs produced by a female salmon at one spawning season is very large. But as a matter of fact the regulations are not enforced in this way: the salmon ascend rivers throughout the summer, and do not spawn till autumn, and the fish that have recently spawned are of no value. Those that are sought are those that have just entered the river. The annual close season is limited to the actual spawning period. In consequence it is only those adults which escape the net, the hook, and the trap which survive to deposit their eggs and milt. However, even thus the close season has a good effect, for it ensures that the adults who do escape shall shed their reproductive products in peace and security, and the eggs are therefore all fertilised and placed in conditions proper for development, while if the fish were disturbed, a greater number would be destroyed, and the eggs of those that were left would not be so properly deposited.

But another method which has been applied to anadromous fish is that of artificial propagation. This has been successful chiefly in the case of Salmonidæ and of the American shad, *Alosa sapidissima*. It seems to me that the application of this measure deserves to be considered carefully. Let us suppose a river visited regularly by salmon for the purpose of spawning. If during the close season pisciculturists are permitted to catch a number of the spawning salmon in the river, strip them of their eggs and milt and hatch them in the most perfectly arranged hatchery, and then turn the fry at a certain stage again into the river, what will be the result? If a greater percentage of eggs can be hatched under artificial conditions than under the natural, then of course the result will be to increase the number of fry produced in the river.

This may be the case supposing that the eggs are preyed upon by other fishes or animals in the natural state, from which they are of course protected in the hatchery. But it would be equally effective to leave the eggs in the natural state and destroy their enemies. The artificially hatched fry are returned to the river soon after hatching, so that they are protected for a very short time, which, however, may be an advantage if in the natural state they are devoured in numbers when first hatched. Of course all this only applies to the case supposed. When artificially fertilised eggs or hatched fry, derived from other places, are put into a river, they will of course add to the salmon population of the river if the conditions necessary for their life prevail in that river.

Considering now the case of the American shad, we find the problem different. The estuaries, when the American Fish Commission commenced operations, were over fished, and some had been entirely depopulated. There was no close season for shad, in fact it was scarcely possible to institute one, for the shad unlike the salmon enters the river only a very short time before it actually spawns, and the immense majority of individuals captured are, like the herrings taken in Britain, either actually ripe or very nearly so. Hence a close season would have meant prohibiting the fishing altogether. Such numbers of shad were taken for many years, that the number of eggs deposited was not nearly sufficient to keep up the numbers of the species. Nearly

all the ripe eggs and milt which ought to have developed into the next generation were actually devoured by the people who ate the shad. The pisciculturists, under the direction of the Fish Commissioner, therefore first invented methods and apparatus by which the eggs of the shad could be artificially fertilised and hatched, and then they organised a system under which every year a large number of the ripe fish captured were stripped of their eggs and milt which were returned either to the same river or others in the form of healthy fry. The consequence is that now the estuaries on the Atlantic side of the United States yield annually a rich harvest of adult shad, and this valuable fishery is absolutely dependent on the piscicultural operations of the National Fish Commission.

Let us now consider the case of the sole. Soles are captured without intermission the whole year round, and their habitat is practically only coextensive with the trawling grounds. Soles do not, our knowledge enables us to infer with some certainty, migrate or travel about to any great extent. There may be of course distant areas where soles are abundant, but the existence of these is not sufficient to maintain the sole population of the extensive areas where they are constantly captured. Now I have shown that the artificial fertilisation and hatching of soles' eggs, though presenting unusual difficulties, is by no means impossible. It is almost impossible to interfere with trawling. Suppose that by further experiments it were shown that millions of soles' eggs could be artificially fertilised, hatched, and returned to the sea. It is evident that this would necessarily have the effect of increasing the supply of soles. For all these eggs would be procured from soles captured for the market, and would, if not artificially hatched, be devoured along with the soles themselves. Of course the expense of providing properly equipped hatcheries and maintaining a staff of men who would collect the eggs and take care of them during development would be very large. But if this expense were provided from the public funds, some return for it would be received by the public in the form of more abundant and cheaper soles. Whether the national account on this item would result in an annual profit or an annual loss I am not yet prepared to say.

On the other hand, it seems to me at least possible that the artificial fertilisation of the eggs would alone be sufficient, and that the artificial hatching in expensive hatcheries would be unnecessary. We have at present little reason to assume that, given a certain number of fertilised eggs more fry would be produced from them by hatching them in artificial apparatus than by placing them in the sea to develop under natural conditions. It is conceivable that the ripe females and males captured by the trawl during the spawning season should be stripped by a man on board a trawler, and the fertilised eggs so obtained should be simply thrown overboard. This would be a direct gain to the sole population of our seas, for every one of those eggs would, if not artificially fertilised, be sent to market inside the female soles and cooked. In fact ripe eggs are now cooked in the ovaries of soles in enormous numbers every spawning season.

Of course much greater results would be effected by simply prohibiting the capture of soles at all from the middle of February to the end of April; but this could only be done by prohibiting trawling during those months, for in my opinion soles once captured in the trawl are usually too much injured to survive if again returned to the sea. I have shown that they do not survive when placed in our aquarium tanks (*see* p. 115). If trawling were prohibited who would compensate the fishermen and capitalists engaged in the business? That would be more expensive than maintaining a national staff of pisciculturists to hatch soles' eggs. On the other hand, we must consider if it is possible under any imaginary system that there should be a man on board every trawler capable of artificially fertilising the eggs of soles during the spawning period. It would scarcely be practicable to send out a trained pisciculturist in every trawler. It is possible, however, in imagination at least, that the skipper of every trawler should carry out the necessary operations, though it would probably be a long time before trawling skippers would possess the necessary knowledge or care sufficiently for the future. If such operations were expected of them they would have to be trained in practical pisciculture, and pass an examination in that subject as they are now required to pass in seamanship.

I make no claim to originality in this idea. Years ago Professor Ewart, of the University of Edinburgh, who has identified himself with the piscicultural work of the Scottish Fishery Board, published the suggestion of a similar scheme to be applied to herrings. I believe it has never been carried out, and I doubt at present if such measures for maintaining the supply of herrings are required. It has occurred to me to consider whether the same scheme might be applied to soles, and I think it quite possible that Professor Ewart's suggestion may in the future lead to very important results.

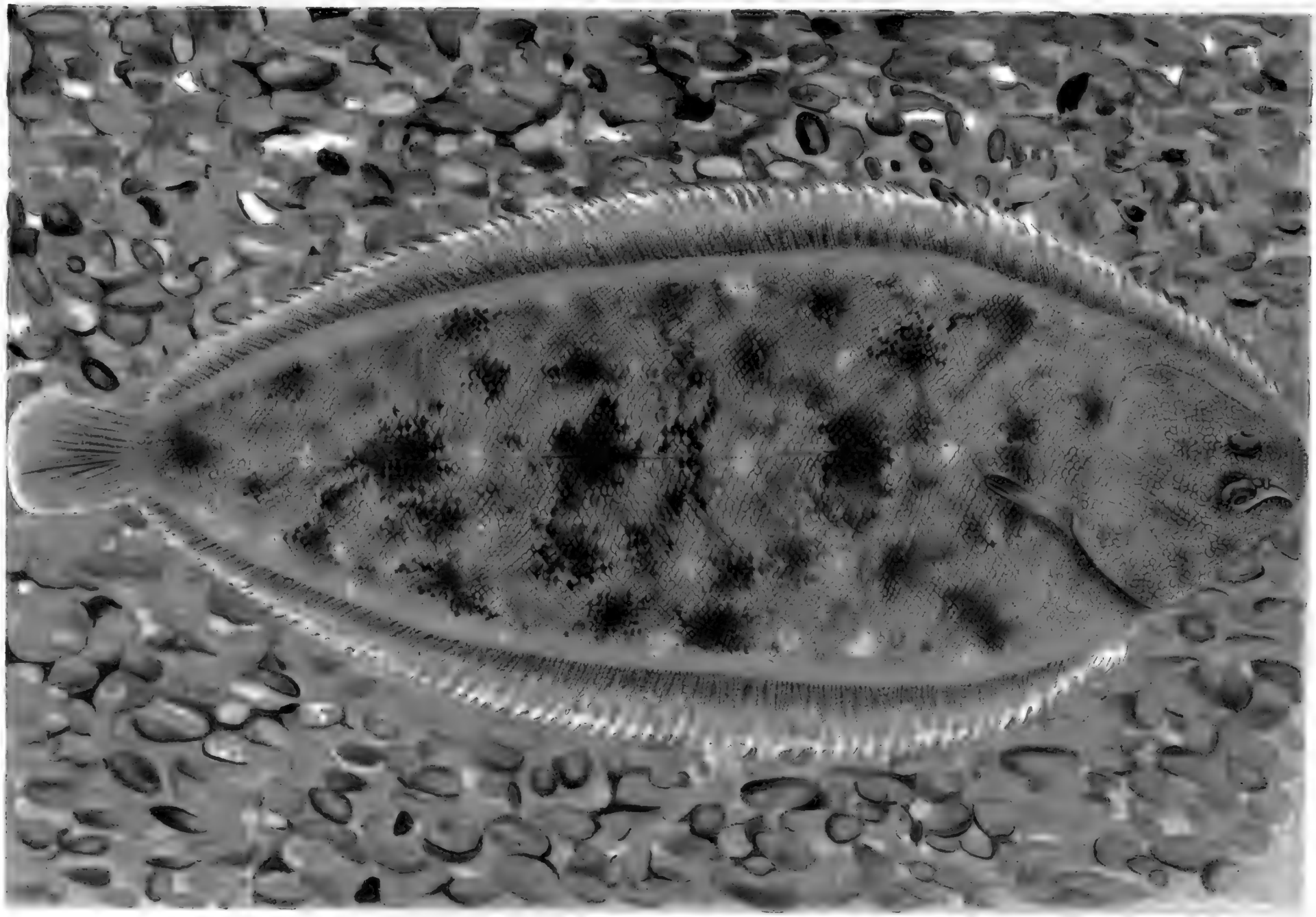
The only other possible methods of increasing the numbers of soles are to increase the supply of food or to diminish the numbers of the natural enemies of the sole. No practical means can be suggested by which the supply of food could be increased, but it might well be worth while to rigorously destroy useless predatory fish which have no value themselves and which live entirely on valuable food fishes. At present trawlers constantly throw back anglers and dog-fishes into the sea alive after they have brought them on deck. I think it would be advisable that these fishes should be systematically killed before being returned to the sea, for if valuable fishes can be diminished in numbers the abundance of their enemies could be reduced also.

There is not much to be said about the domestication of soles. It is certain that soles will live in captivity and grow to a large size. The Association is now making arrangements to keep young soles in a large piece of enclosed sea-water at Sheerness. But it is evident that the capture of young soles to be merely retained in captivity and killed when mature will not prevent the diminution of the numbers in the sea. If the adults were kept in captivity and their eggs taken and reared a new industry of sole-raising might be started, but it is doubtful whether this would compensate for the extermination of soles from the great trawling grounds.

PLATES.

Plate I.

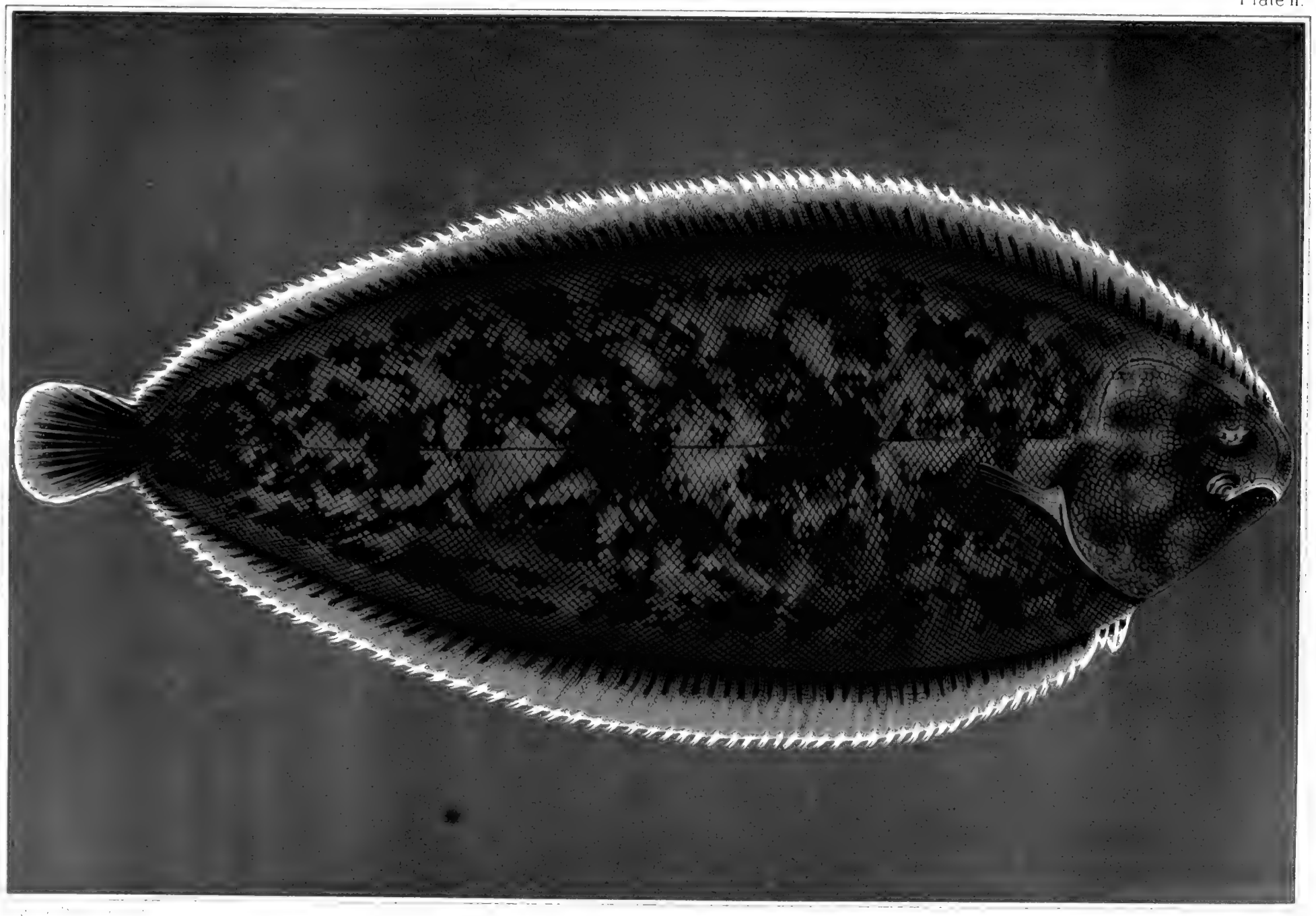
Drawing of a living Sole, lying on coarse bright-coloured gravel, in a shallow porcelain dish full of sea-water, and exposed to daylight from a south window.



SOLEA VULGARIS

Plate II.

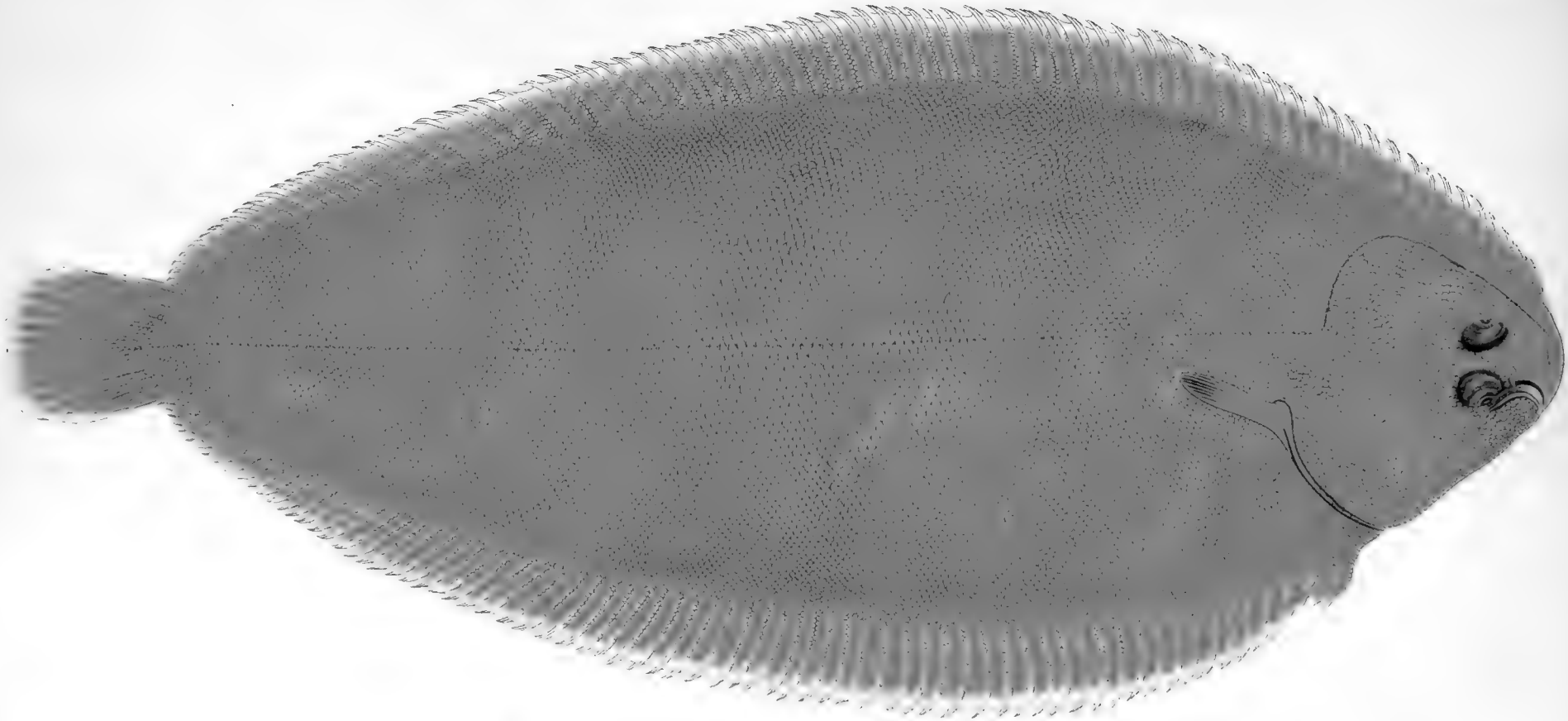
Drawing of the same specimen as that represented in Plate I lying on washed coal in a deep wooden tub and shaded from the light.



SOLEA VULGARIS

Plate III.

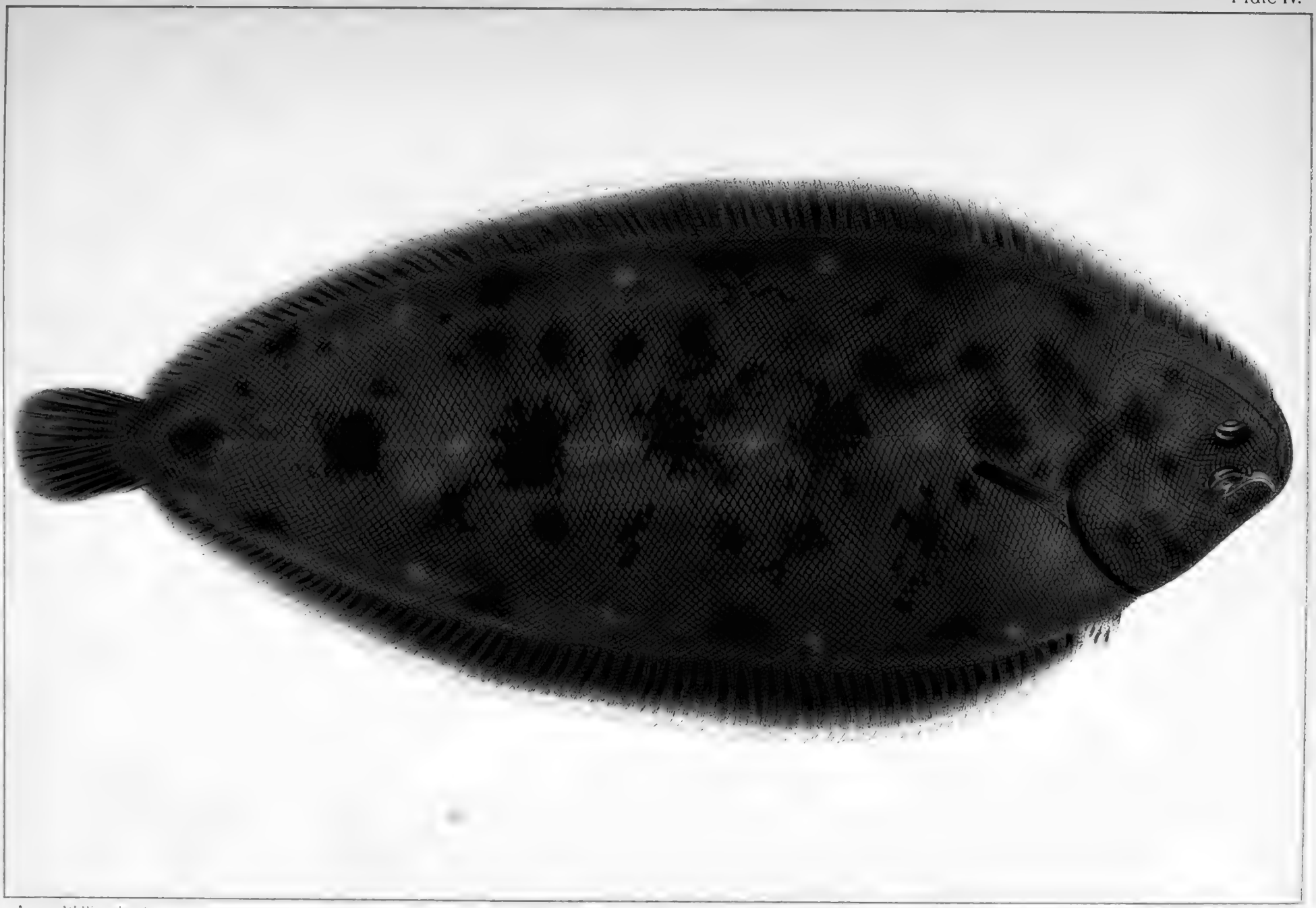
Drawing of a living Sole, not the same specimen as represented in Plate I, lying in a shallow dish of white porcelain full of sea-water and exposed to strong daylight from a south window.



Solea vulgaris

Plate IV.

Drawing of the specimen represented in Plate III on the day after its death.



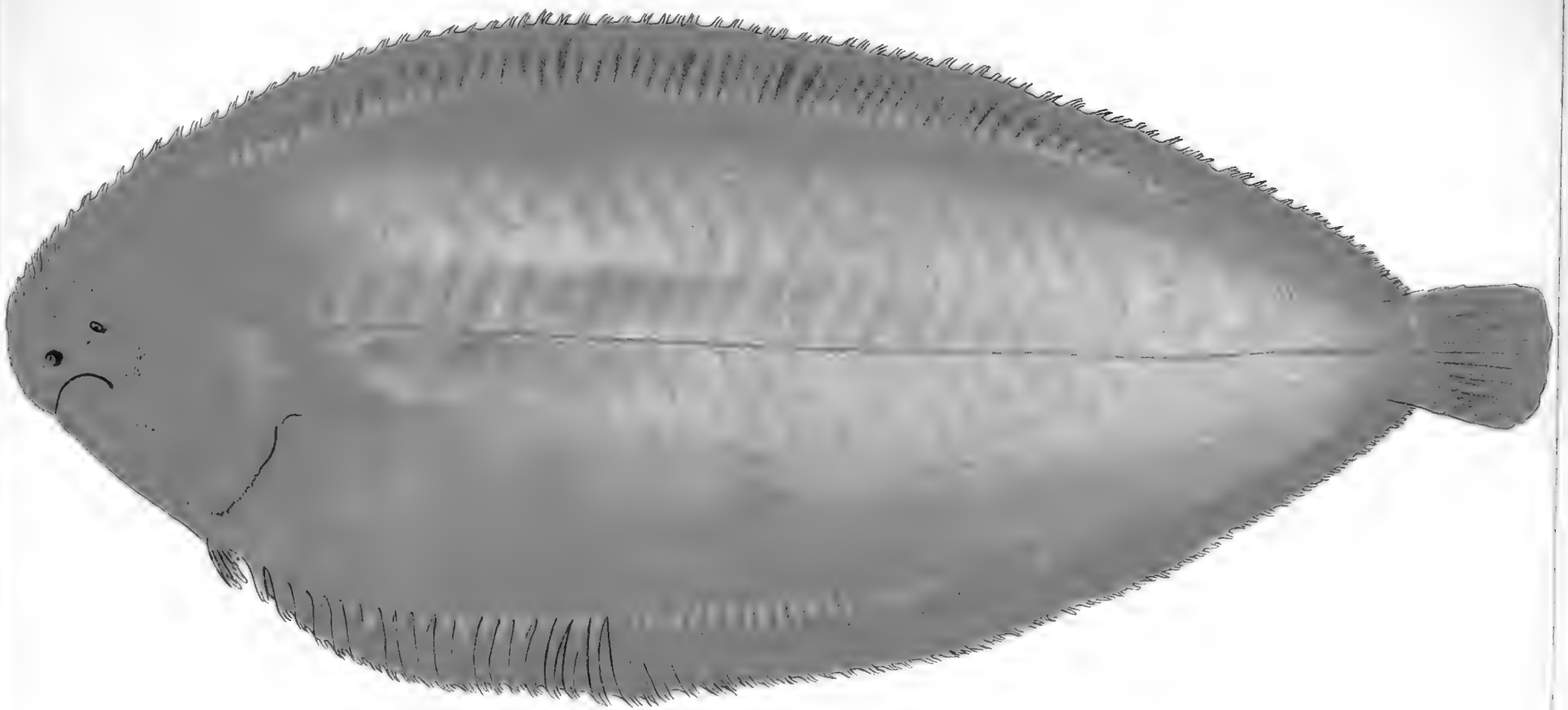
Annie Willis pinxit

Lith. Werner & Winter, Frankfurt a/M

SOLEA VULGARIS

Plate V.

The lower (left) side of the Common Sole. Two specimens of the parasite *Phyllonella soleæ* are shown on the skin behind the head just below the lateral line.



Annie Willis pinxit

Lith. Werner & Winter, Frankfurt a/M.

SOLEA VULGARIS

Plate VI.

Fig. 1. The Lemon or Sand Sole (*Solea lascaris*), natural size.

Fig. 2. Lower side of the head of the same, showing the dilated anterior nostril.

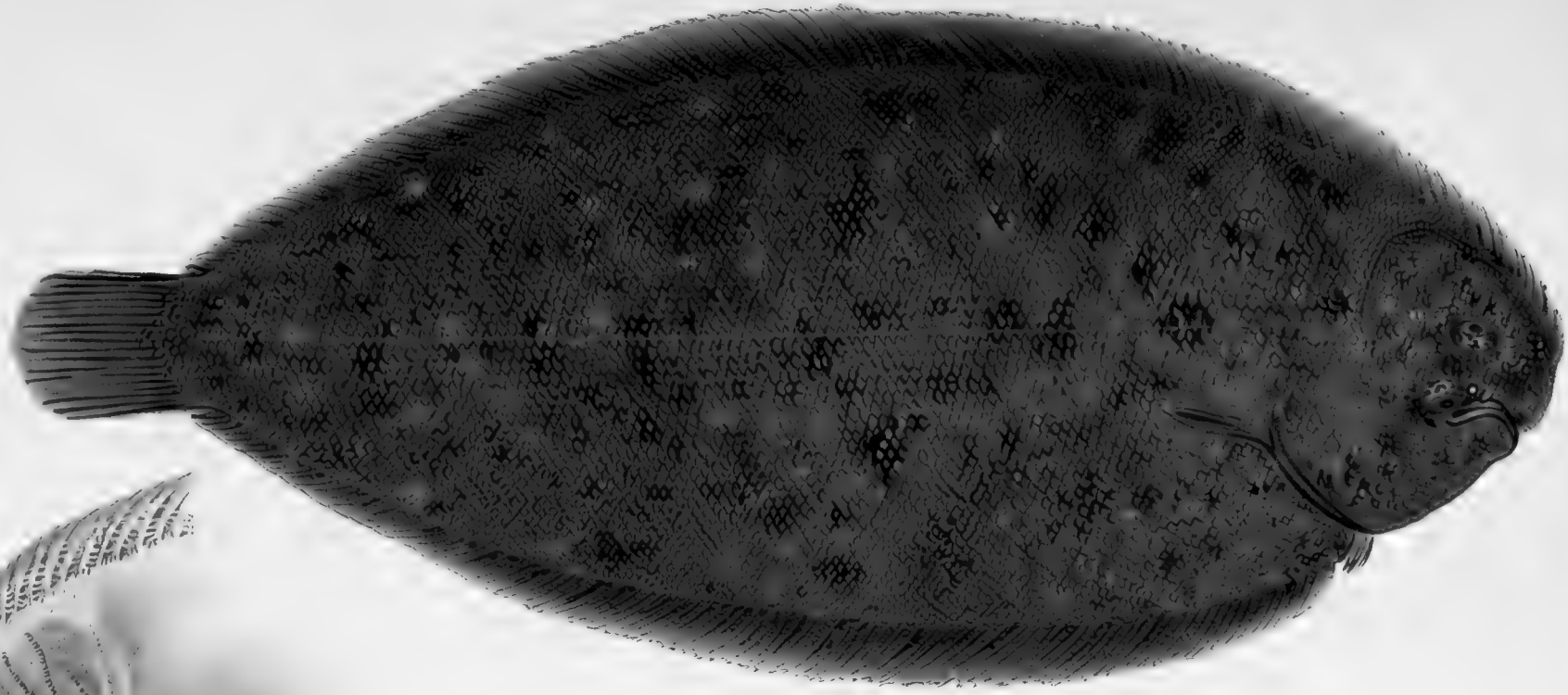


Fig 1

Fig 2

Annie Willes pinxt

SOLEA LASCARIS

Plate VII.

Fig. 1. The Thickback (*Solea variegata*), natural size.

Fig. 2. Lower side of the head of the same.

Fig. 3. The Solenette (*Solea lutea*), natural size.

Fig. 4. Lower side of the same.

Fig 2

Fig 1

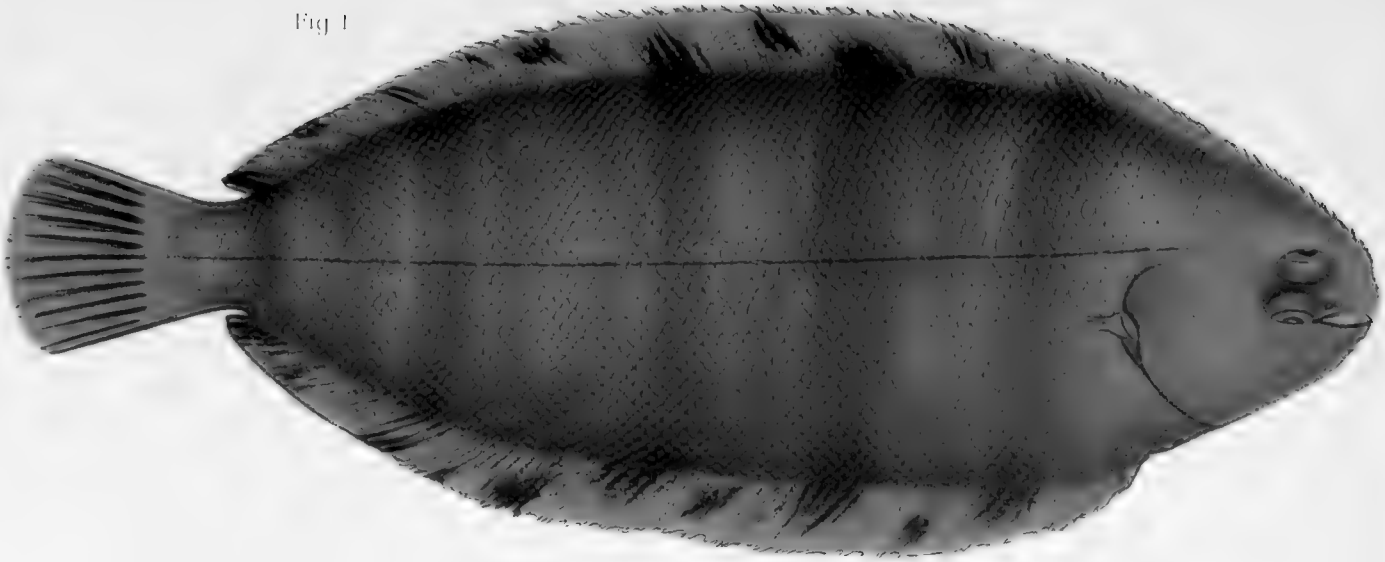


Fig 3.

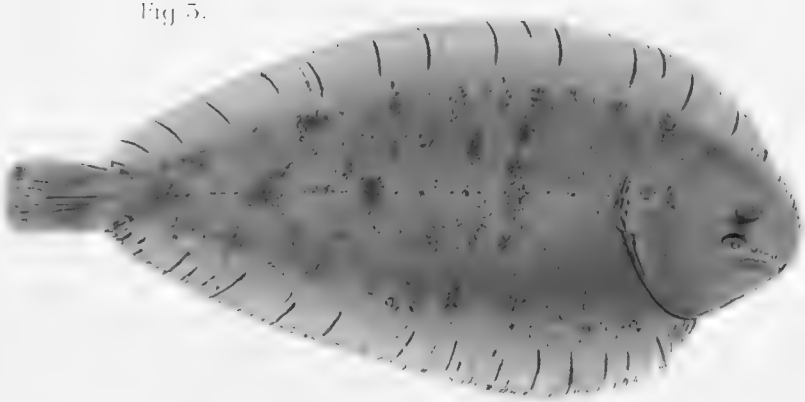
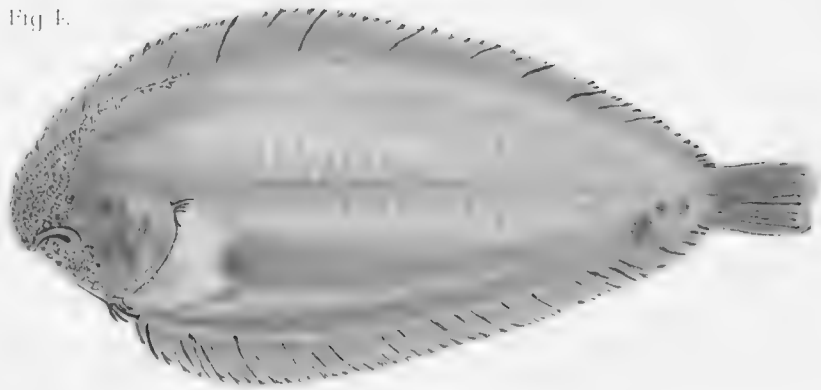


Fig 4.

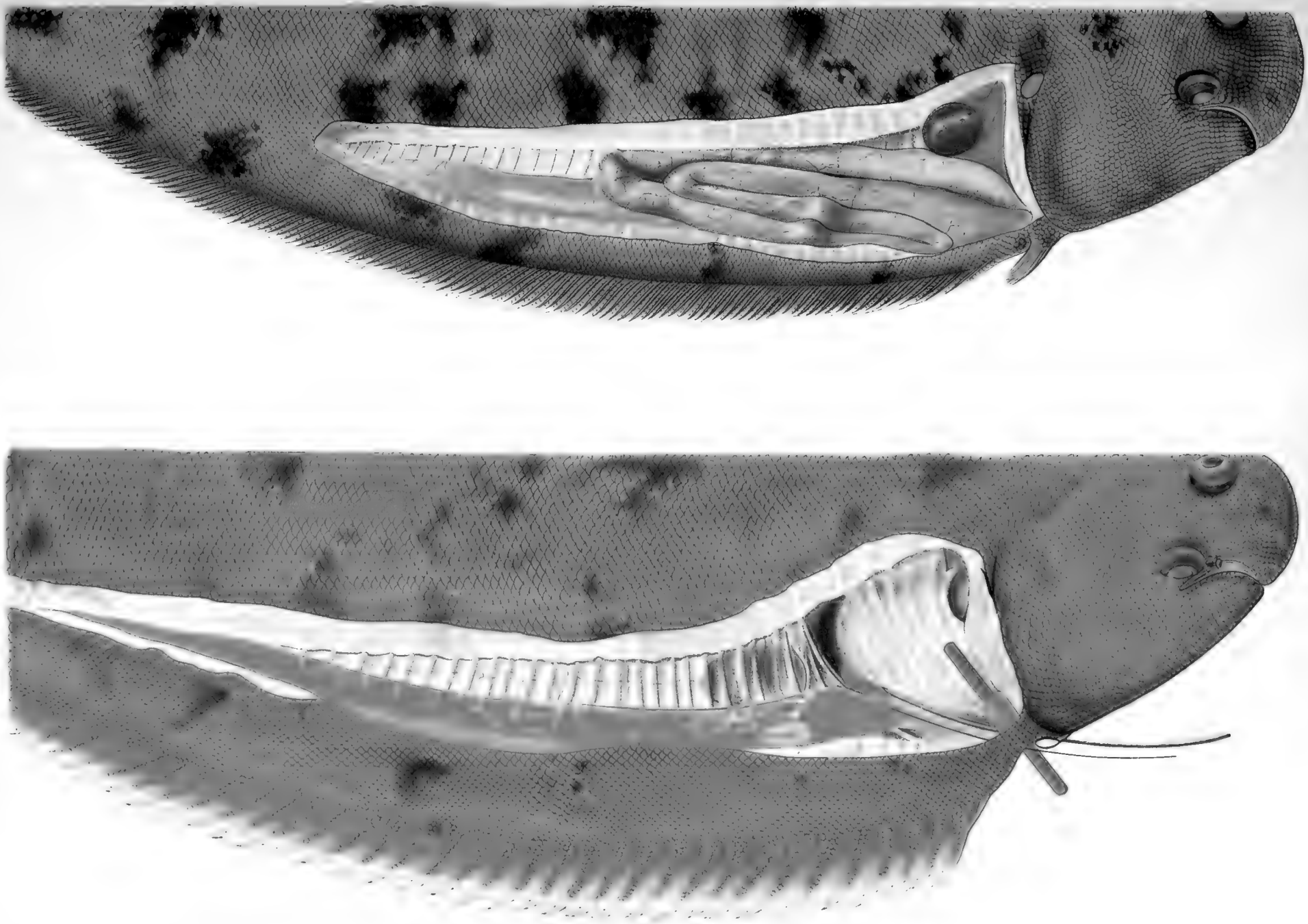


Figs. 1 & 2, SOLEA VARIEGATA
Figs. 3 & 4, SOLEA LUTEA

Plate VIII.

Fig. 1. The viscera of the female Common Sole *in situ*, natural size.

Fig. 2. The body cavity of the female Common Sole after all the viscera have been removed except the ovary and kidneys, which are left *in situ*. The wooden rod passes through the anus, the blue probe passes through the external aperture of the common oviduct up into the left ovary, the black bristle passes into the urinary bladder which lies beneath the oviduct.

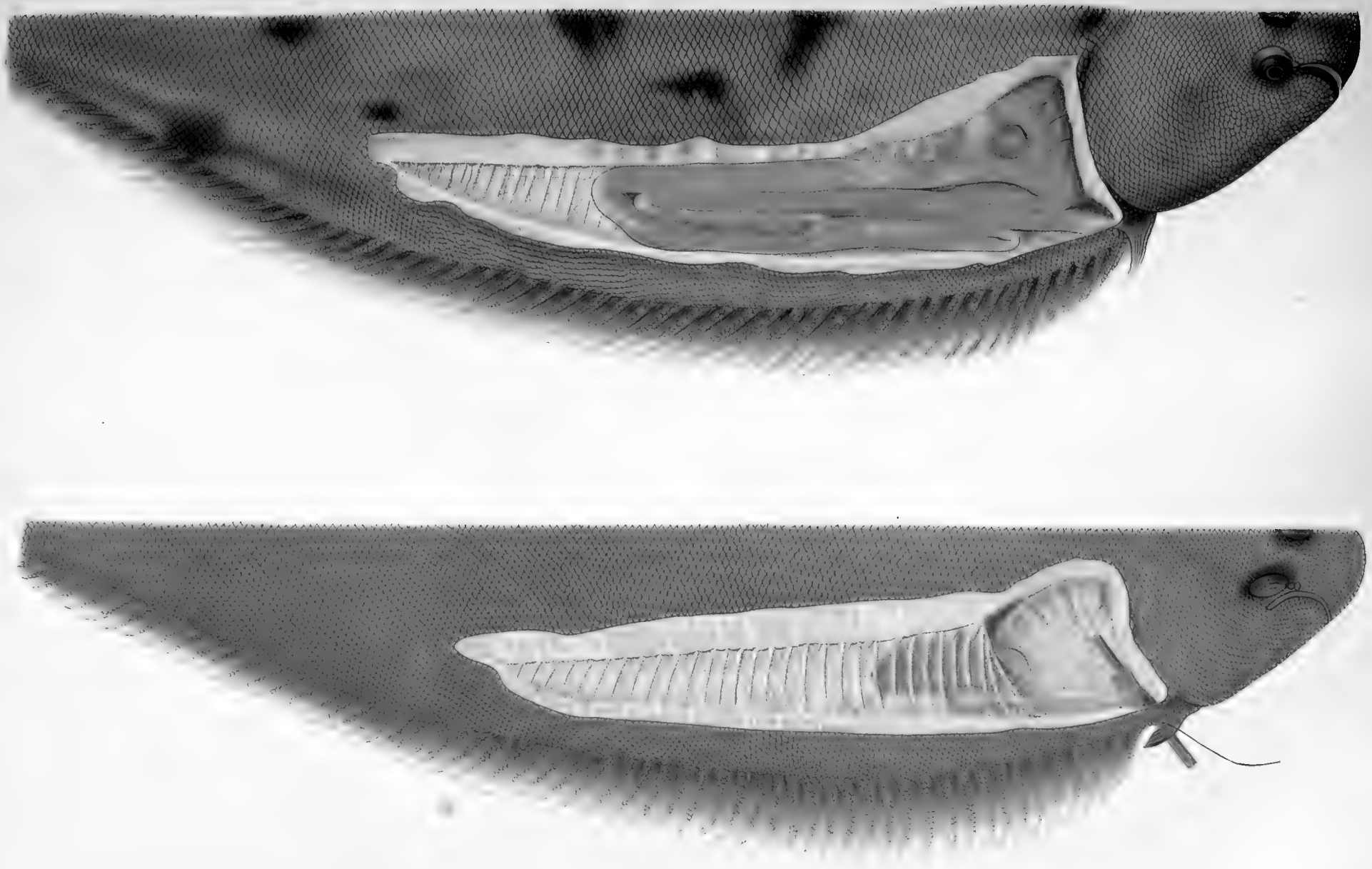


Solea vulgaris ♀

Plate IX.

Fig. 1. The viscera of the male Common Sole *in situ*, natural size.

Fig. 2. The body cavity of the male Common Sole after all the viscera have been removed except the testes and kidneys, which are left *in situ*, natural size. The wooden rod passes through the anus, the black bristle passes into the urinary bladder, which lies beneath the cords containing the testicular ducts.



Solea vulgaris ♂

Plate X.

Fig. 1. The skeleton of the Common Sole; the branchial arches, jaws, and bones of the paired fins have been removed, all the other bones are in their natural position in relation to one another.

Fig. 2. One of the dorsal fin-rays: *a.* from the side; *b.* from the front.

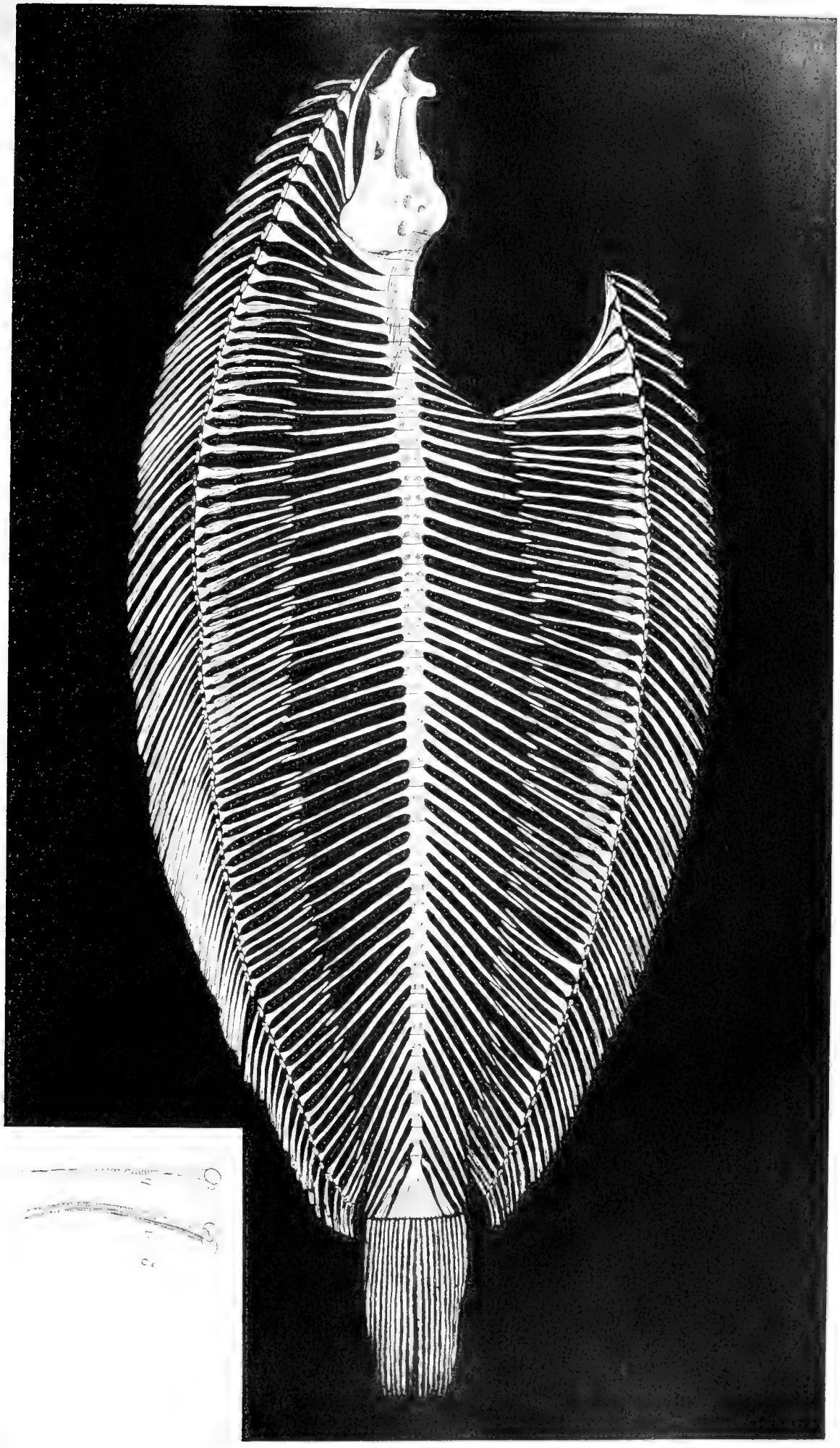


Plate X

Fig. 1. The superficial bones of the right or upper side of the head of the Common Sole.

Fig. 2. The superficial bones of the left or lower side.

Reference letters :—

hm,	hyomandibular.	*q*,	quadrate.
ms,	mesopterygoid.	*x*,	maxilla.
mt,	metapterygoid.	*px*,	premaxilla.
m,	mandible.	*o*,	opercular.
pt,	pterygoid.	*po*,	preopercular.
pa,	palatine.	*io*,	interopercular.
s,	symplectic.	*so*,	subopercular.

Fig. 3. The bones of the branchial arches and paired fins, lateral view.

Fig. 4. The bony branchial arches spread out and seen from the dorsal side.

Reference letters and numbers :—

bb 1,	1st basibranchial.	14,	2nd epibranchial.
bb 2,	2nd ditto.	16,	2nd hypobranchial.
bb 3,	3rd ditto.	17,	3rd pharyngobranchial.
bh,	basihyal.	18,	3rd epibranchial.
hh,	hypohyals.	19,	3rd ceratobranchial.
ch,	ceratohyal.	20,	3rd hypobranchial.
cb 1,	1st cerato-branchial.	21,	4th epibranchial.
cb 2,	2nd ditto.	25,	post-temporal.
lp,	lower pharyngeal.	26,	supra-clavicular.
up,	upper pharyngeal.	27,	clavicle.
2,	stylohyal.	28,	jugular.
3,	epihyal.	29,	scapula.
8,	1st pharyngobranchial.	30,	coracoid.
9,	1st epibranchial.	31,	pubic.
11,	1st hypobranchial.		

Fig. 5. The skull, showing the separate bones and their sutures, from the right side.

Fig. 6. The same from the left side.

Fig. 7. The same from the dorsal side.

Fig. 8. The posterior surface.

Reference letters :—

b.o.	basioccipital.	*pa.*	parietal.
s.o.	supraoccipital.	*l.f.*	left frontal.
ex.o.	exoccipital.	*r.f.*	right frontal.
ep.o.	epiotic.	*pa.s.*	parasphenoid.
pt.o.	pterotic.	*vo.*	vomer.
op.o.	opisthotic.	*mes.e.*	mesethmoid.
pr.o.	proötic.	*r.ect.e.*	right ectethmoid.
sp.o.	sphenotic.	*l.ect.e.*	left ditto.

Plate X

Fig. 1. The superficial bones of the right or upper side of the head of the Common Sole.

Fig. 2. The superficial bones of the left or lower side.

Reference letters :—

hm,	hyomandibular.	*q*,	quadrate.
ms,	mesopterygoid.	*x*,	maxilla.
mt,	metapterygoid.	*px*,	premaxilla.
m,	mandible.	*o*,	opercular.
pt,	pterygoid.	*po*,	preopercular.
pa,	palatine.	*io*,	interopercular.
s,	symplectic.	*so*,	subopercular.

Fig. 3. The bones of the branchial arches and paired fins, lateral view.

Fig. 4. The bony branchial arches spread out and seen from the dorsal side.

Reference letters and numbers :—

bb 1,	1st basibranchial.	14,	2nd epibranchial.
bb 2,	2nd ditto.	16,	2nd hypobranchial.
bb 3,	3rd ditto.	17,	3rd pharyngobranchial.
bh,	basihyal.	18,	3rd epibranchial.
hh,	hypohyals.	19,	3rd ceratobranchial.
ch.	ceratohyal.	20,	3rd hypobranchial.
cb 1,	1st cerato-branchial.	21,	4th epibranchial.
cb 2,	2nd ditto.	25,	post-temporal.
lp,	lower pharyngeal.	26,	supra-clavicular.
up,	upper pharyngeal.	27,	clavicle.
2,	stylohyal.	28,	jugular.
3,	epihyal.	29,	scapula.
8,	1st pharyngobranchial.	30,	coracoid.
9,	1st epibranchial.	31,	pubic.
11,	1st hypobranchial.		

Fig. 5. The skull, showing the separate bones and their sutures, from the right side.

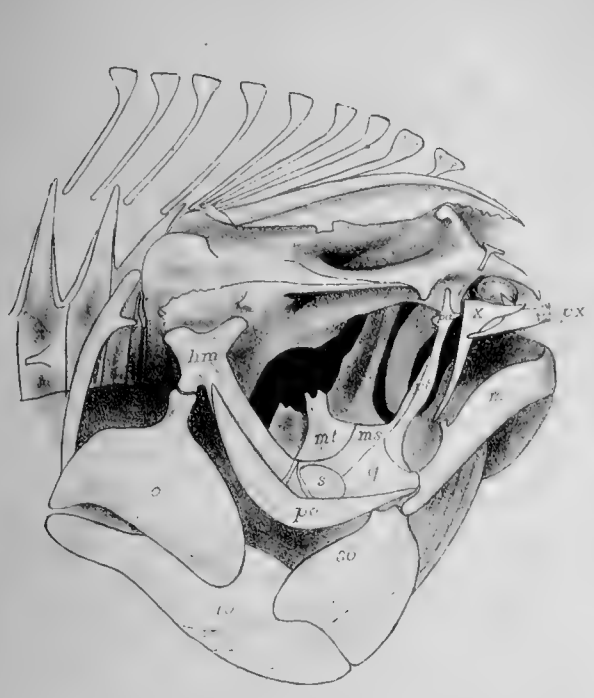
Fig. 6. The same from the left side.

Fig. 7. The same from the dorsal side.

Fig. 8. The posterior surface.

Reference letters :—

b.o.	basioccipital.	*pa.*	parietal.
s.o.	supraoccipital.	*l.f.*	left frontal.
ex.o.	exoccipital.	*r.f.*	right frontal.
ep.o.	epiotic.	*pa.s.*	parasphenoid.
pt.o.	pterotic.	*vo.*	vomer.
op.o.	opisthotic.	*mes.e.*	mesethmoid.
pr.o.	proötic.	*r.ect.e.*	right ectethmoid.
sp.o.	sphenotic.	*l.ect.e.*	left ditto.



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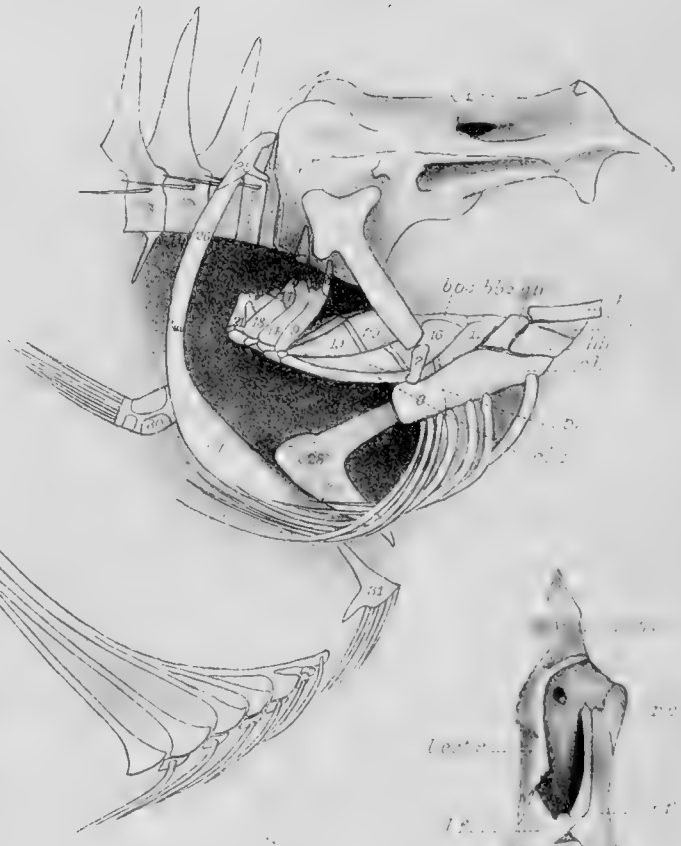

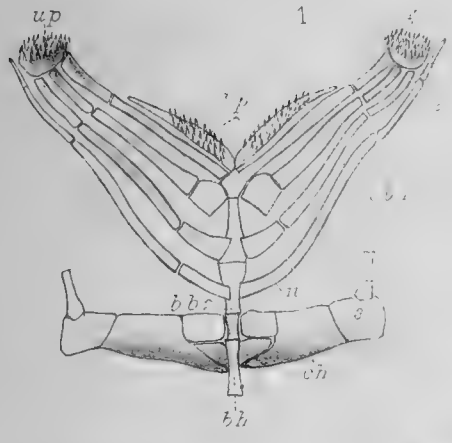

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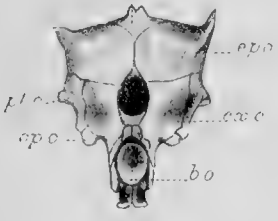

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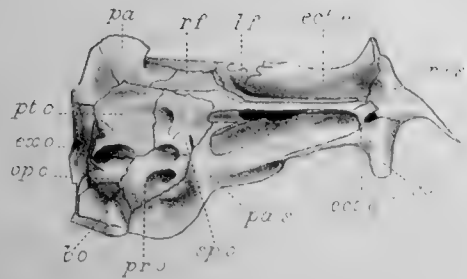

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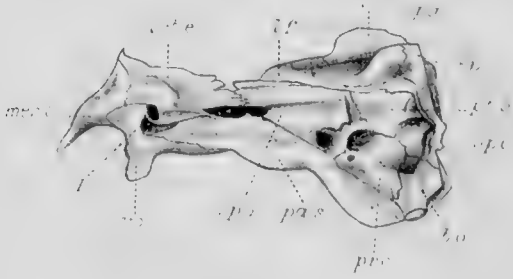

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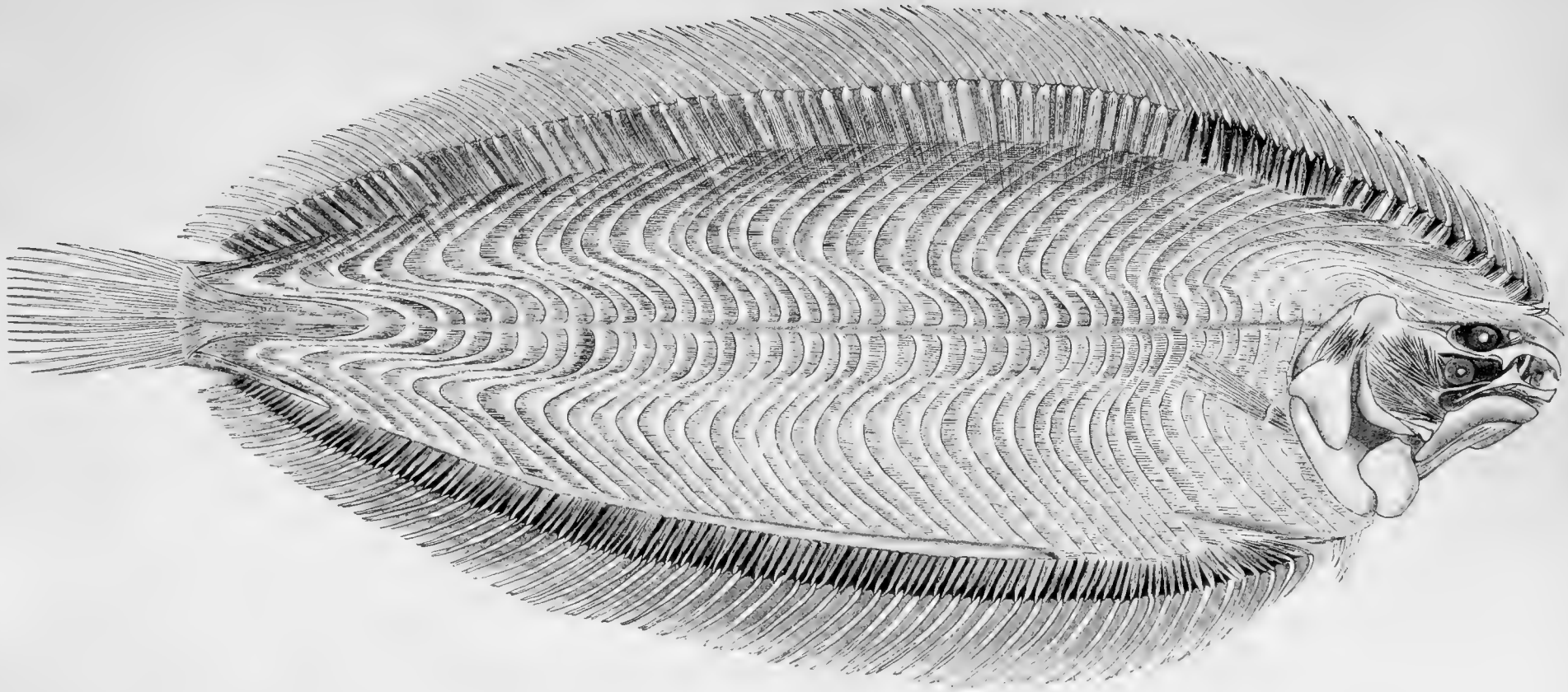
J.T. Cunningham, del

Solea vulgaris

Plate XII.

General view of the musculature of the Common Sole seen from the right side, after removal of the skin. The superficial abductors of the ventral fin have been removed, to expose the elevators and depressors of the ventral fin-rays which lie beneath them; the same dissection has been made along the anterior fourth of the dorsal fin.



Solea vulgaris

T. Cunningham del.

Plate XIII.

Fig. 1. Transverse section of the right ovary of a young Common Sole, $7\frac{1}{4}$ inches long, killed May 2, 1889; magnified 45 times, linear.

f.e. fibrous tissues forming the wall of the ovary.
o.g. ovigerous lamellæ.
b.v. blood-vessels, ovarian artery and vein.

Fig. 2. Portion of an ovigerous lamella from transverse section of an ovary of a Sole $10\frac{1}{2}$ inches long, killed January 26, 1889; magnified 450 times.

g.e. germinal epithelium.
o. ova.

Fig. 3. Section of an ovum approaching maturity, from the ovary of a Sole killed when spawning was almost finished, on April 11, 1889; magnified 70 times.

b.v. blood-vessels.
f.e. follicular epithelium.
f.m. follicular membrane.
v.m. vitelline membrane.

Fig. 4. Transverse section of the right testis of a Sole 9 inches long, immature; magnified 45 times.

f.e. fibrous envelope.
r.t. radial testicular tubes.
l.t. longitudinal testicular tubes.

Fig. 5. Closed end of one of the radial testicular tubes shown in Fig. 4; magnified 450 times.

f.e. fibrous envelope.
g.e. male germinal epithelium.

Fig. 5*a*. Longitudinal portion of a testicular tube from the same section cut transversely, containing spermatoblasts and ripe spermatozoa; magnified 450 times.

Fig. 6. Transverse section of the cord containing the testicular ducts from an adult male Sole killed in the breeding season, March 23, 1889; magnified 70 times.

f.t. fibrous tissue.
l.t. the testicular ducts.
u.b. urinary bladder lined by an epithelium.

Fig. 7. Spermatozoon of Dab (*Pleuronectes limanda*); magnified 500 times.

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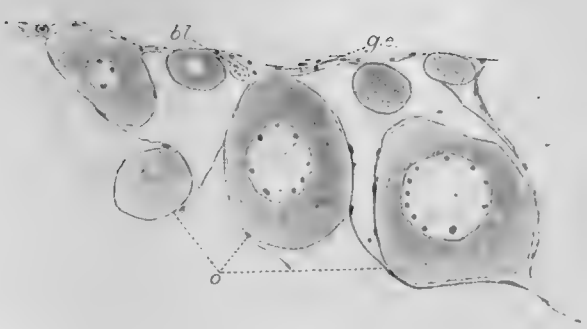

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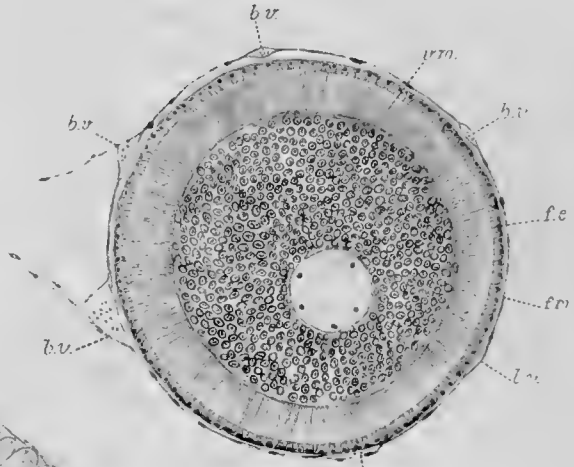

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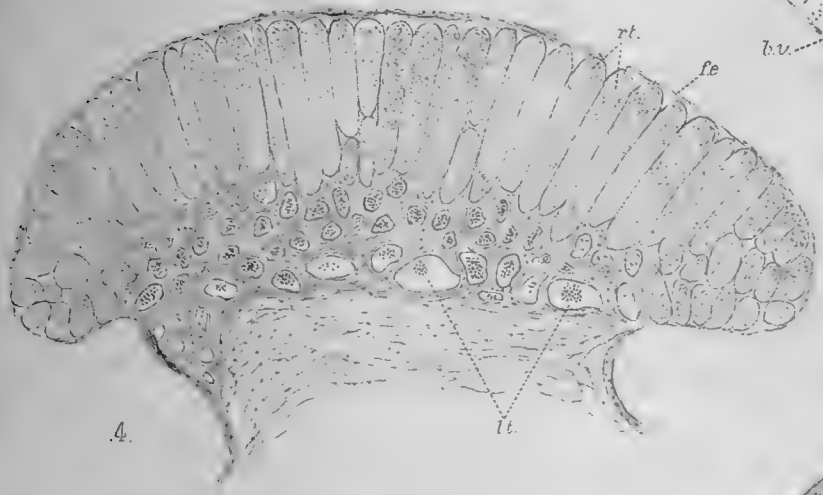

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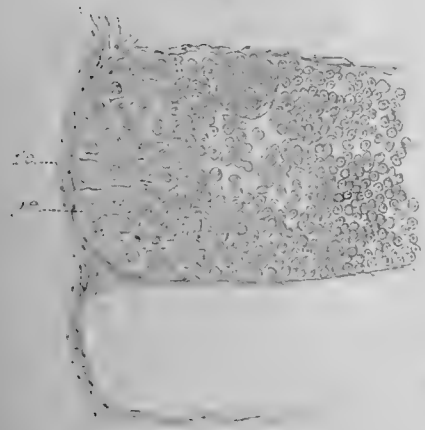

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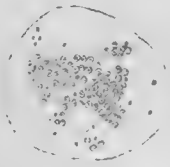

5a.

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Plate XIV.

Fig. 1. Scale of Common Sole from middle of body; magnified.

Fig. 2. One of the lateral line scales of the same.

Fig. 3. Scale of Thickback.

Fig. 4. Scale of Lemon or Sand Sole.

Fig. 5. Scale of Solenette.

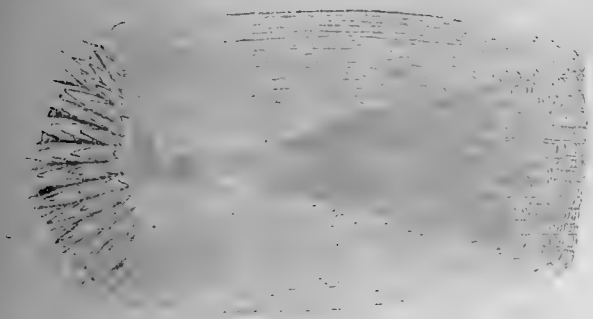
Fig. 6. *Phyllonella soleæ*, the parasite from the skin of the Common Sole; magnified.

p.s. posterior sucker.
p. aperture for the penis.
u. aperture of the uterus.
a.g. anterior glandular areas.

Fig 6*a*. Egg of same, magnified 100 times.

Fig. 7. Ideal longitudinal section of the skin along the lateral line of the Common Sole; magnified 70 times.

ep. epidermis.
c. chromatophores.
d.t. dermal tube.
s.c. scale in section.
f. fibrous tissue of the derma with areolar tissue in spaces.
p. external pores.
s.o. sense organ.
n. nerve.



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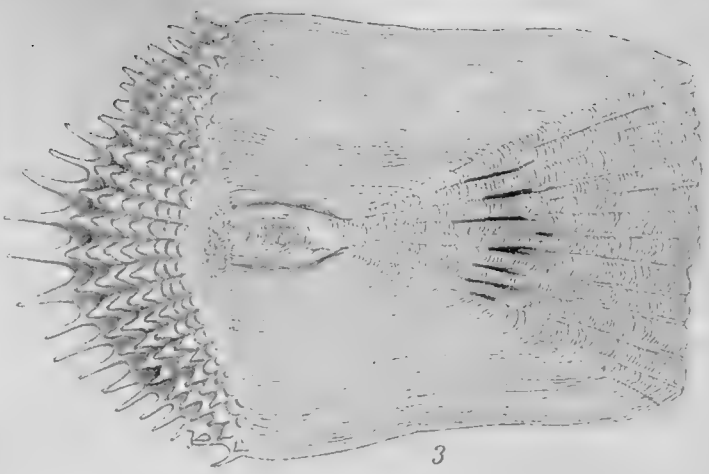

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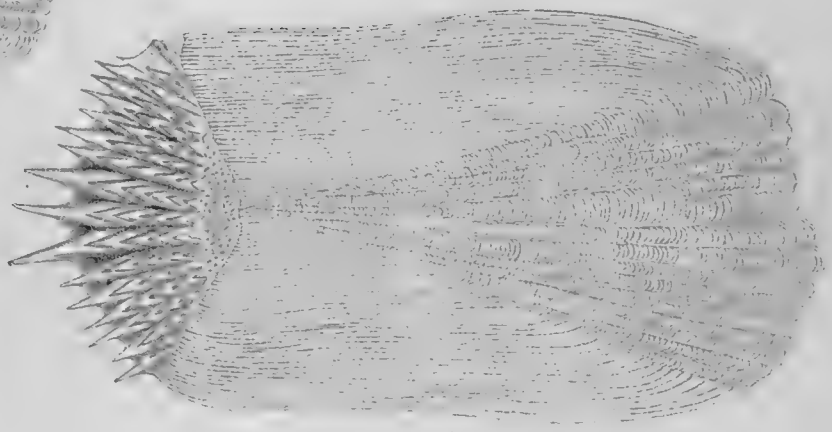

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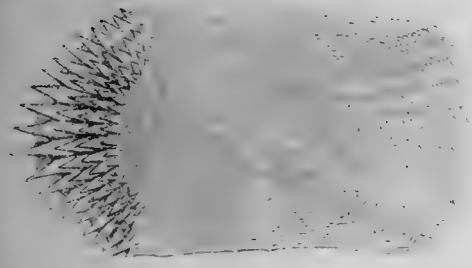

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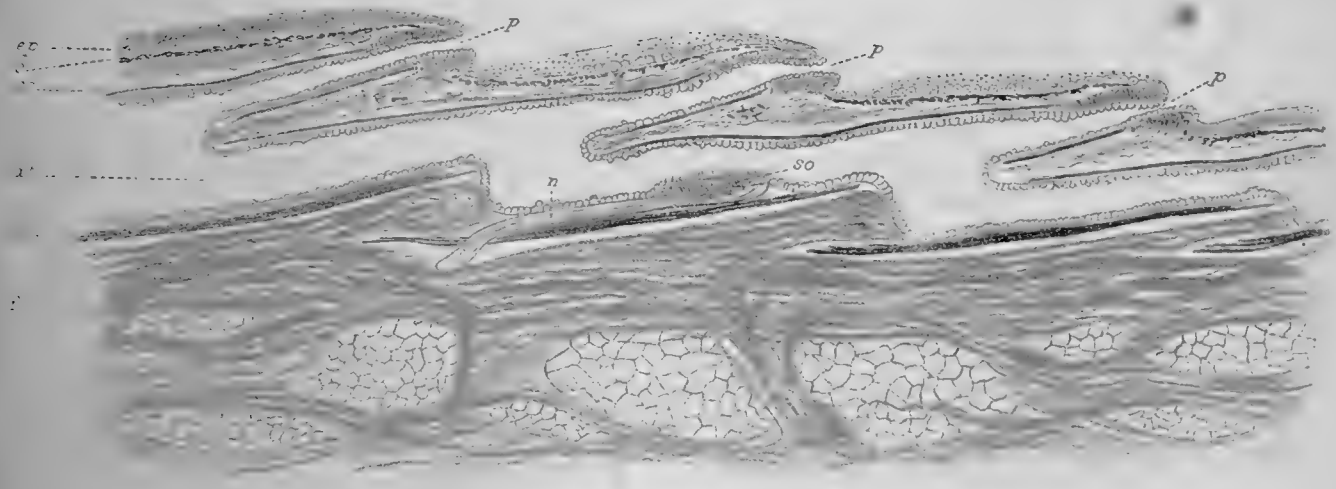

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Solea vulgaris.

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Plate XV.

Fig. 1. Section of a portion of the skin of the lower side of head of the Common Sole; magnified 70 times. Reference letters as in Fig. 7, Pl. XIV, with the addition of *f f*, tactile filaments.

Fig. 2. Lower side of the head of the Sole dissected to show the cutaneous nerves: natural size.

V 2. Maxillary branch of the 5th.
V 2 *a*. palato-nasal branch of 5th.
V 2. mandibular branch of 5th.
VII 1. mandibular branch of 7th.
VII 2. hyoidean branch of 7th.
VII 2 *a*. opercular branch of 7th.
X 6 *a*. supra-temporal branch of vagus.
X 6 *b*. another anterior branch of the vagus.

Fig. 3. Egg of Common Sole taken in tow-net in Mount's Bay, March 1, 1889. Magnified 45 times. *bl*. blastoderm, *y.s*. yolk segments, *o.g*. oil globules.

Fig. 4. An egg of the same, artificially fertilised, March 23, 7 a.m.; drawn March 24, 5 p.m.; same magnification.

Fig. 5. An egg of the same, artificially fertilised, March 23, 7 a.m.; drawn March 25, 12 noon; same magnification.

Fig. 6. An egg, fertilised artificially, April 12, 1889; dranw April 15, 4 p.m. Both black and coloured pigment cells present, the latter green by reflected light; *e*. eye, *m.s*. mesoblastic somites.

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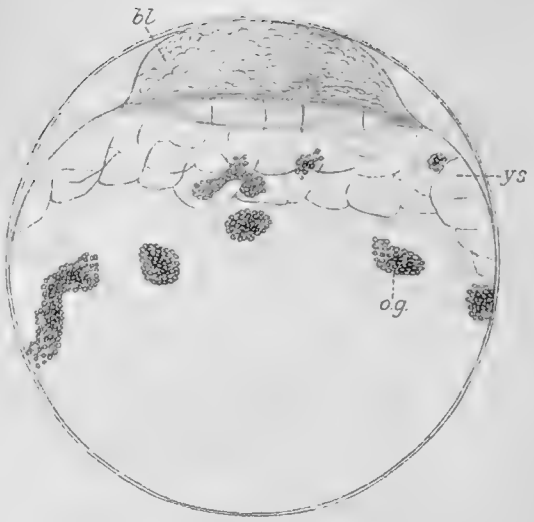

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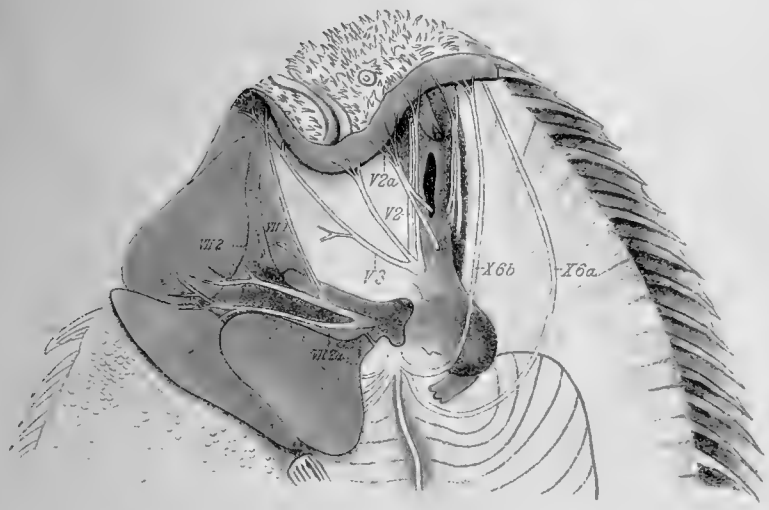

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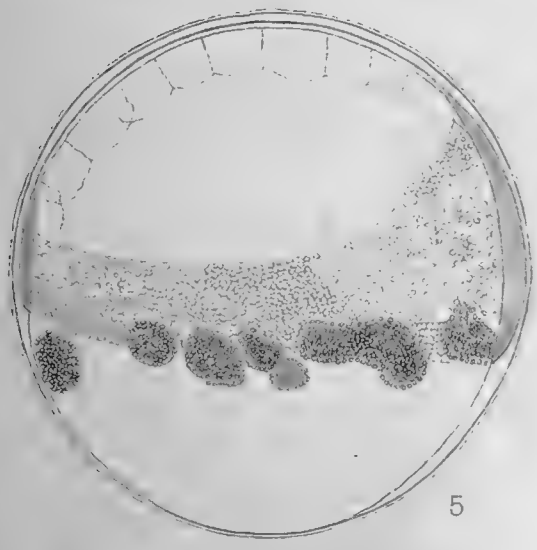

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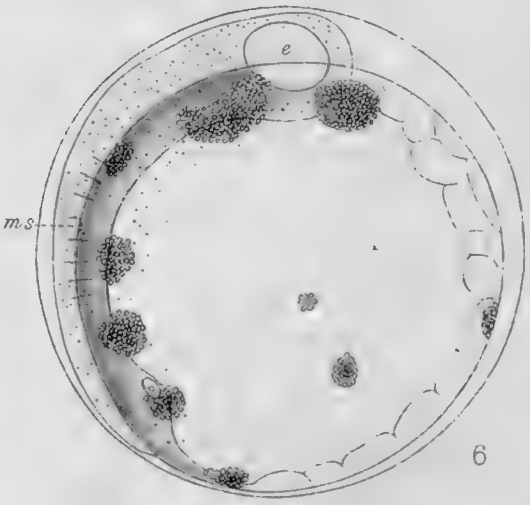

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Solea vulgaris

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Plate XVI.

Fig. 1. Egg of Common Sole, artificially fertilised, April 12, 1889, 10 a.m.; drawn April 15, 4 p.m. Magnified 45 times; same stage as that shown in Pl. XV, Fig 6, in profile. *o.g.* oil globules.

Fig. 2. An egg of same taken in tow-net off Plymouth (near the Mewstone), March 29, 1889; drawn March 30; same magnification. *e.* eye. *yk.* yolk.

Fig. 3. Larva of same taken 4 m. south of the Mewstone, March 30, 1889; right side; magnified 35 times. *yk.* yolk. *au.* auditory organ. *na.* nasal capsule.

Fig. 4. Larva of same, hatched March 28, from egg taken off Penlee Point, March 27, left side; magnified 35 times. *ht.* heart. *pt.* pectoral fin. *int.* intestine.

Fig. 5. Young Common Sole $\frac{3}{4}$ inch long, taken in Mevagissey Harbour, May 15, 1889; magnified $8\frac{1}{4}$ times.

Fig. 6. Egg of the Thickback (*Solea variegata*), taken in tow-net S. of the Eddystone; drawn April 21, 1889; magnified 45 times.

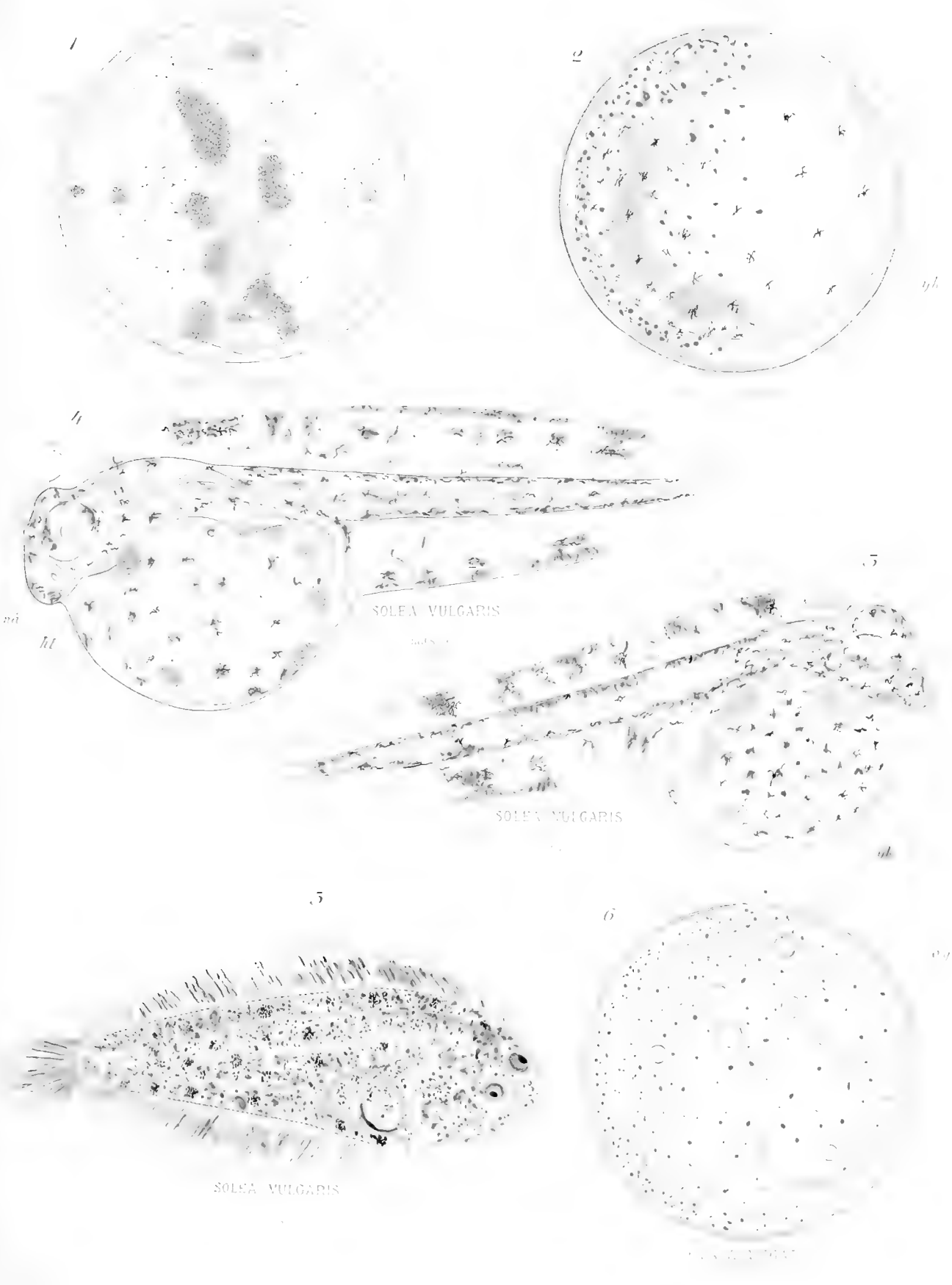

Fig 1-5 SOLEA VULGARIS Fig 6 SOLEA VARIEGATA

Plate XVII.

Fig. 1. Larva of Thickback newly hatched, April 24, 1889; magnified 35 times. Pigment as seen by reflected light. *yk.* yolk.

Fig. 2. Larva of same two days after hatching, April 23, 1889. Same magnification *pt.* pectoral fin. *ht.* heart.

Fig. 3. Larva of Flounder (*Pleuronectes flesus*), two days after hatching, February 20, 1889, from egg artificially fertilised; magnified 35 times.

Fig. 4. Larva of same six days after hatching, February 24, 1889, from the same lot as the preceding; same magnification.

Fig. 5. Young Flounder taken in Mevagissey Harbour, April 2, 1889; drawn April 5; magnified about 18 times.

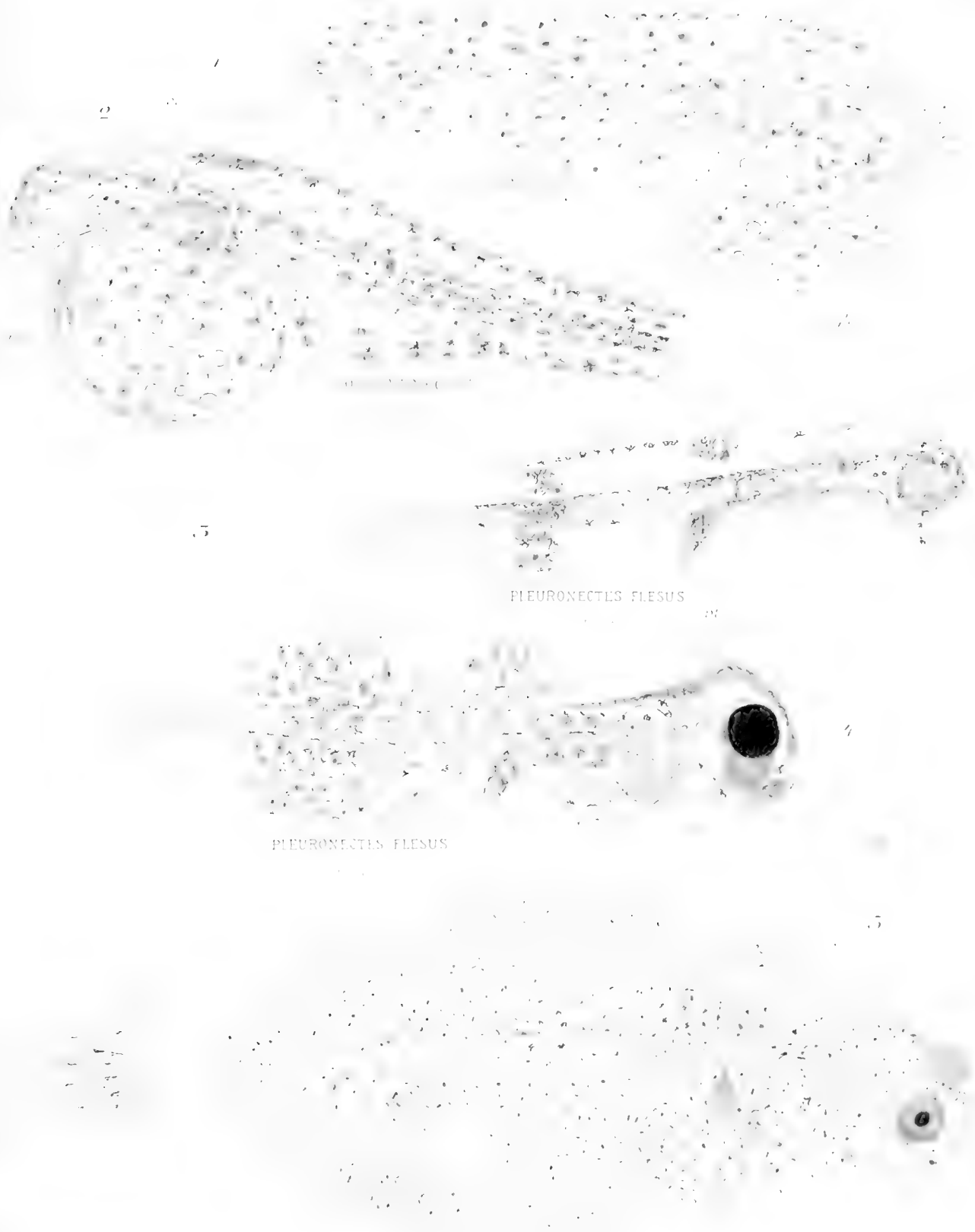

Fig. 1, 2. SOLEA VARIEGATA. Fig. 3–5. PLEURONECTES FLESUS.

Plate XVIII.

Fig. 1. Young Flounder (*Pleuronectes flesus*) taken in Mevagissey Harbour, April 2, 1889; magnified about 14½ times. *pv.* pelvic fin.

Fig. 2. Larva of Dab (*Pleuronectes limanda*) newly hatched, from artificially fertilised egg, March 11, 1889; magnified 35 times. *pt.* pectoral fin. *yk.* yolk.

Fig. 3. Larva of Merry Sole (*Pleuronectes microcephalus*), March 25, 1889, four days after hatching, from artificially fertilised egg; same magnification. *l.* liver. *ht.* heart.

Fig. 4. Larva of Plaice (*Pleuronectes platessa*), February 27, 1889, five days after hatching, from artificially fertilised egg; same magnification. *a.* anus. *nch.* notochord.

Fig. 5. Young Brill (*Rhombus lævis*) taken at surface of water in Sutton Pool, June 1, 1889; natural size.

Fig. 1. PLEURONECTES FLESUS. Fig. 2. PL. LIMANDA. Fig. 3. PL. MICROCEPHALUS.
Fig. 4. PL. PLATESSA. Fig. 5. RHOMBUS LAEVIS.

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